BALLARD MINE

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

SUPPLEMENTAL TECHNICAL MEMORANDUM MONITORED NATURAL ATTENUATION REMEDY FOR GROUNDWATER

FINAL – REVISION 2

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ACRONYOMS AND ABBREVIATIONS

AOC	Administrative Order on Consent
A/Ts	Agencies and Tribes
BLM	United States Department of the Interior, United States Bureau of Land Management
BRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CO	Consent Order
COCs	contaminants of concern
DO	dissolved oxygen
DSR	Data Summary Report
ET	evapotranspiration
ICs	institutional controls
LTM	long-term monitoring
MCL	maximum contaminant level
MNA	Monitored Natural Attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ORP	oxygen reduction potential
P4	P4 Production, LLC
PCLs	preliminary cleanup levels
POC	points of compliance
PRB	permeable reactive barrier
RA	remedial action
RAOs	remedial action objectives
RD	remedial design
RI/FS	Remedial Investigation / Feasibility Study
SAP	Sampling and Analysis Plan
SEP	sequential extraction procedure
Tribes	Shoshone Bannock Tribes
USEPA	United States Environmental Protection Agency
USFS	United States Department of Agriculture, United States Forest Service

1 INTRODUCTION

1.1 GENERAL INFORMATION

This Monitored Natural Attenuation (MNA) Technical Memorandum for the Ballard Mine Site (the Site) was developed in support of the Remedial Investigation and Feasibility Study (RI/FS) of P4 Production, L.L.C. (P4's) legacy mine sites per the 2009 Order on Consent/Consent Order (2009 CO/AOC; USEPA, 2009a). P4 entered into the 2009 CO/AOC with the United States Environmental Protection Agency (USEPA); the Idaho Department of Environmental Quality; the United States Department of Agriculture, United States Forest Service (USFS); the United States Department of the Interior, United States Bureau of Land Management (BLM); and the Shoshone-Bannock Tribes (Tribes), collectively referred to as the Agencies and Tribes (or A/Ts). The RI/FS is being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the associated regulations of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

In 2014, P4 completed the RI for the Ballard Mine, which is summarized in the *Ballard Mine RI Report – Final* (*Ballard RI Report;* MWH, 2014). This cornerstone document was followed by preparation of the Ballard Mine Feasibility Study (Ballard FS) once the *Ballard RI Report* was approved. The Ballard Mine FS Report was prepared and submitted as two technical memoranda: *Ballard Mine FS Report Memorandum #1 – Site Background and Screening of Technologies – Final* and *Ballard Mine FS Report Memorandum #2 – Screening, Detailed, and Comparative Analysis of Remedial Alternatives – Final* (*Ballard FS Memorandums #1 and #2*; MWH, 2016 and 2017a). This *Ballard Mine MNA Memo* (*MNA Memo*) specifically provides supporting information related to the MNA component of the preferred/selected groundwater remedial alternative as presented in *Ballard FS Memorandum #2*. This *MNA Memo* was prepared to support the selected groundwater remedy at the request of the A/Ts prior to issuing the Proposed Plan for the Site.

1.2 PURPOSE

The objective of this *MNA Memo* is to integrate data, evaluations, and other lines of evidence that support the use of MNA as a component of the preferred groundwater remedy at the Site. The majority of this information, as summarized in this memorandum, resides within previous reports and P4 responses to A/T comments on the *Ballard RI Report* and *Ballard FS Memorandums #1 and #2*. This memo consolidates the supporting information into a single document and discusses data within the framework of current USEPA guidance for MNA (USEPA, 2015). It identifies data gaps, where present, and proposes a general plan for future data collection to further evaluate physical plume characteristics and attenuation mechanisms.

This *MNA Memo* is considered a supplemental document to the Ballard FS and will be included in the administrative record and referenced in the Proposed Plan for the Site. Other possible future reports and work plans, as discussed in Section 4.0, will be submitted to the A/Ts under separate cover or included in either the Remedial Design (RD) or Remedial Action (RA) Work Plans, as appropriate.

1.3 DOCUMENT ORGANIZATION

This *MNA Memo* consists of five sections as follows:

Section 1.0 Introduction – provides general Site information, the purpose of the memo, and the relationship between the memo and other RI/FS reports.

Section 2.0 Site Background Information for MNA Selection – summarizes background information for the Site, discusses potential receptors identified in the *Ballard Baseline Risk Assessment* (*Ballard BRA)*, and describes the preferred alternatives (or selected Site remedy) and regulatory basis for which MNA is used as a polishing step for alluvial and Wells Formation groundwater.

Section 3.0 Technical Basis for MNA – describes the MNA mechanisms that are found at the Site, provides empirical MNA data for the Site groundwater plumes and the data that support MNA, and provides conclusions regarding the use of MNA as a polishing step at the Site.

Section 4.0 Plans for Implementation – outlines the proposed pre-design studies to further evaluate attenuation processes and the long-term monitoring (LTM) program.

Section 5.0 References

2 SITE BACKGROUND INFORMATON FOR MNA SELECTION

This section presents a summary of the Site background including relevant RI findings and descriptions of the aquifer characteristics. Also presented in this section is a summary of potential receptors that could be affected by the selection of MNA, and a discussion of the other components of the combined remedy that supports the selection of MNA as a component of the proposed groundwater remedy. Lastly, the relevant information related to the selection of MNA as a polishing step for Site groundwater and the regulatory basis for this selection is discussed.

2.1 SITE BACKGROUND

The Ballard Site is located approximately 13 miles north-northeast of Soda Springs, Caribou County, Idaho (**Drawing 2-1**) and is accessed via the Blackfoot River Road, from State Highway 34. The Ballard Mine is comprised of external mine waste dumps, open pits, an abandoned haul road, and the Ballard Shop Area, all of which cover approximately 534 acres of disturbance. P4 owns approximately 865 acres of surface rights and has a surface easement from the State of Idaho on an additional 360 acres (**Drawing 2-2**). The adjoining properties are all privately held ranching and farming properties.

2.1.1 Site Geologic and Hydrogeologic Characteristics

The geology of the Site is characterized by linear, north-south trending, fault-bounded ranges and basins formed by extensional tectonism within the Basin and Range and Rocky Mountain Physiographic Provinces. Extensional tectonism overprints an earlier period of compressional tectonics that included major overthrusting, which resulted in synclinal-anticlinal folds and predominantly thrust faulting during the Paleocene and Upper Cretaceous periods, respectively.

Ranges in southeast Idaho are generally composed of deformed Paleozoic and Mesozoic sedimentary rocks, including thick marine clastic units, cherts, and limestones. During Permian times the Phosphoria Formation was deposited, creating the western phosphate field, which includes the southeast Idaho phosphate resource area. The Phosphoria Formation has four members (from oldest to youngest): the Meade Peak Phosphatic Shale, Rex Chert, Cherty Shale, and Retort Phosphatic Shale. The Meade Peak Member, which ranges in thickness from about 55 to 200 feet, is the source of most of the extracted phosphate ore. Another significant sedimentary unit in the area is the Triassic Dinwoody Formation, which is made up of upper and lower units consisting of limestone, siltstone, and shale layers. The lower Dinwoody Formation directly overlies the Phosphoria units in the stratigraphic section. The Meade Peak Member of the Phosphoria Formation is underlain by the upper unit of the Wells Formation, which consists of sandstone interbedded with limestone and dolomite. **Drawing 2-3** depicts the surficial geology at and adjacent to the Ballard Mine, and **Drawing 2-4** depicts cross-sections through the Site.

The groundwater system in the region is divided between these geologic units into: (1) local shallow groundwater systems within basin-fill alluvium, (2) shallow to deep intermediate systems within sedimentary bedrock units (locally the Dinwoody Formation), and (3) regional groundwater flow systems within deeper sedimentary bedrock units (locally the Wells Formation).

The alluvial flow system is generally unconfined and may interact directly with the local surface water systems in the valleys resulting in gaining and losing sections of streams at different locations. Where the bedrock sedimentary units contact alluvium, groundwater will similarly move between the alluvium and bedrock depending on the hydraulic characteristics of the units and the hydraulic gradients at different locations.

In the bedrock units, the Dinwoody, Phosphoria, and Wells Formations are the principal sedimentary formations in the area of the Ballard Site through which significant groundwater flow may occur. The Dinwoody Formation typically supports intermediate groundwater flow systems. The Phosphoria Formation does not support any major groundwater flow systems and is relatively impermeable due to low vertical hydraulic conductivity (Ralston et al., 1980) although water may flow through fractures of the Rex Chert Member. The Wells Formation supports a regional groundwater system and has higher hydraulic conductivity compared to other bedrock units in the region. In general, the groundwater flow systems in the Dinwoody Formation are separated from the deeper Wells Formation by the low hydraulic conductivity of the Phosphoria Formation (in particular the Meade Peak Member).

2.1.2 Site Nature and Extent Summary

As described in detail in the *Ballard RI Report*, the nature and extent of contaminants associated with the Ballard Site were identified through extensive sampling of the various media within and downslope of the Site and review of numerous investigations that confirmed characteristics of the mined materials and mining practices. The primary known/recognized source of contaminants associated with phosphate mining in southeast Idaho is the Meade Peak Member of the Phosphoria

Formation. With few exceptions, constituents (any metal/non-metal that occurs naturally in the geologic formations at the Site) are leached from the waste rock in mine dumps through precipitation contact, which either directly runs off as surface water, mostly during the spring snowmelt, or infiltrates into the mine dump and appears as contaminated springs at the toe of the dumps. Water can continue downward through the mine waste rock dumps, infiltrate into the underlying shallow groundwater, and then appear as seeps in the stream channels leading from the Site or as shallow groundwater plumes leading from the source area.

Upland soils, collected primarily from the soils overlying the waste rock dumps, and along haul roads and other operational areas, are comprised in many cases of center waste shale of the Meade Peak Member that contain elevated constituents (as would be expected) as does the vegetation that grows upon the mine dumps. Sediments and surface water in the stream channels leading from the waste rock dumps and associated ponds also contain elevated contaminants. However, the constituent concentrations rapidly decrease in the downstream direction and are most elevated in the on-Site pond locations. Similarly, riparian soils and riparian vegetation contain contaminants, which are most elevated near the dumps and on-Site pond locations, but rapidly decrease in the downstream direction. Groundwater contamination occurs in various geologic units with the highest concentrations near source areas (i.e., mine pits and waste rock dumps) as discussed further below.

In summary, the areal distribution of constituents is limited to the waste rock in the mine dumps and pit backfill throughout the Site, and contamination is transported a relatively short distance downslope by a combination of surface water and groundwater that have elevated constituents because of precipitation contact with waste rock.

2.1.3 Description of Site Groundwater Plumes

The nature and extent of the groundwater plumes are described fully in the *P4 Sites RI/FS Work Plan* (MWH, 2011) and *Ballard RI Report,* and a summary is presented herein sufficient to frame the discussion of MNA. As noted above, there are three aquifers beneath the Site: the alluvial groundwater, Dinwoody Formation, and Wells Formation. Of these, only groundwater in the alluvial and Wells Formation aquifers have contaminants of concern (COCs) in concentrations that exceed the preliminary cleanup levels (PCLs) based on the enforceable National Primary Drinking Water Regulations Maximum Contaminant Levels (MCLs). Because arsenic, cadmium, and selenium exceed their PCLs in various monitoring well locations over several groundwater sampling events, and because the *Ballard BRA* identified arsenic and selenium as preliminary groundwater COCs, these chemical elements are considered the Site's COCs for groundwater. A summary of their concentrations in groundwater collected from the alluvial and Wells Formation aquifers is presented in **Table 2-1**. Arsenic and cadmium concentrations in groundwater are only analytes of concern in isolated monitoring well locations at the Site. However, selenium is the primary groundwater COC because it is detected above its PCL in groundwater monitoring locations throughout the Site in both the alluvial and Wells Formation aquifers. As a result, selenium will be the focus of the groundwater remedial action and is the focus of the discussion herein.

The extent of contamination in the alluvial aquifer has been defined through the installation of monitoring wells, temporary direct-push boreholes, and monitoring of spring and seep locations as shown on **Drawing 2-5**. Characterization of the Wells Formation relied only on permanent monitoring wells. Both the alluvial and Wells Formation plumes (areas exceeding PCLs) are discussed below.

The Dinwoody Formation is not impacted at the Ballard Site, and in fact, where groundwater has been encountered in the Dinwoody Formation, it is a source of clean upwelling groundwater, as verified by the potentiometric and water quality conditions observed in nested well set MBW032/MMW029/MMW033 (refer to the *Ballard RI Report* for additional details).

2.1.4 Physical Characterization of Aquifers

Alluvial Aquifer. During the RI, the alluvial aquifer was characterized with 16 monitoring wells and 105 direct-push borings with associated grab groundwater samples. At the Site, the shallow alluvial hydrostratigraphic unit is defined as containing colluvium, alluvium, and uppermost weathered (decomposing) bedrock. These lithologies have similar hydrogeologic properties and functionally form a single hydrogeologic unit. The stratigraphy within the alluvial unit is complex with interfingered lenses (beds) of materials ranging from silts/clays to gravels that may pinch out horizontally. These layers have widely ranging hydraulic conductivities. The hydraulic conductivities measured by slug testing of several alluvial monitor wells at the P4 Sites are provided in **Table 2-2**.

TABLE 2-1

SUMMARY OF COC CONCENTRATIONS IN BALLARD SITE MONITOR WELLS

Well	**MAW008**	**MBW006**	**MBW009**	**MBW011**	**MBW026**	**MBW027**	**MBW028**	**MBW032**	**MBW048**	**MBW130**	**MBW131**
Aquifer	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial
Arsenic											
Minimum	--	--	--	--	--	--	--	--	--	--	--
Maximum	--	--	--	--	--	--	--	--	--	--	--
Mean	--	--	--	--	--	--	--	--	--	--	--
Count (n)	--	--	--	--	--	--	--	--	--	--	--
Cadmium											
Minimum	0.000334	<0.000125	<0.0003	<0.0003	0.000893	<0.0006	<0.0006	0.000602	<0.000125	<0.0003	<0.0003
Maximum	0.000334	0.000027	0.00106	0.00017	0.000893	0.000401	0.00049	0.001555	0.000662	0.00046	0.00014
Mean	0.000334	0.0002789	0.000469	0.0003	0.000893	0.000375	0.00041	0.000954	0.000351	0.00040	0.00032
Count (n)	1	7	7	6	1	7	7	7	7	5	6
Selenium											
Minimum	**0.0709**	**0.300**	0.00206	**0.159**	**0.221**	**0.18**	**0.62**	**0.605**	<0.0005	0.0004	0.002
Maximum	**0.0709**	**0.684**	**0.0598**	**0.744**	**0.221**	**0.969**	**1.25**	**3.95**	0.000534	0.0013	0.0046
Mean	**0.0709**	**0.419**	**0.0133**	**0.596**	**0.221**	**0.459**	**0.980**	**1.58**	0.000578	0.0007	0.0029
Count (n)	1	7	7	6	1	7	7	7	7	6	6

TABLE 2-1

SUMMARY OF COC CONCENTRATIONS IN BALLARD SITE MONITOR WELLS

Well	**MBW135**	**MMW017**	**MMW018**	**MW15A**	**MW16A**	**MMW032**	**MMW006**	**MMW020**	**MMW021**	**MMW030**	**MMW031**
Aquifer	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Alluvial	Wells Fm.	Wells Fm.	Wells Fm.	Wells Fm.	Wells Fm.
Arsenic											
Minimum	--	0.0023	0.0008	**<0.0125**	0.00112	0.000815	0.0032	0.0012	0.0015	**0.0267**	0.000456
Maximum	--	0.0035	0.00137	**<0.0125**	0.00112	0.000815	0.0032	0.0012	0.0015	**0.0267**	0.000456
Mean	--	0.0029	0.00109	**<0.0125**	0.00112	0.000815	0.0032	0.0012	0.0015	**0.0267**	0.000456
Count (n)	--	2	2	1	1	1	1	1	1	1	1
Cadmium											
Minimum	<0.0003	<0.0006	<0.000125	<0.0003	<0.000125	<0.0003	<0.00008	**0.0069**	<0.000125	<0.00008	<0.00008
Maximum	0.00003	0.0018	<0.00008	0.000285	<0.00008	0.000433	<0.000125	**0.0133**	0.000061	<0.000125	<0.000125
Mean	0.00030	0.0007	<0.00008	0.000329	<0.00008	0.000345	<0.000125	**0.0101**	0.000229	<0.000125	<0.000125
Count (n)	6	9	9	7	7	7	9	9	10	8	8
Selenium											
Minimum	<0.0005	**0.0937**	0.0259	**1.09**	0.0019	0.0013	**0.069**	0.0088	0.046	<0.0005	0.00068
Maximum	0.000663	**0.321**	0.0369	**3.2**	0.018	0.0027	**0.157**	**0.439**	**0.0593**	0.00116	0.00156
Mean	0.000637	**0.143**	0.0296	**2.2**	0.009	0.0019	**0.094**	**0.157**	**0.052**	0.00066	0.00113
Count (n)	6	10	10	7	7	7	10	11	11	8	8

Notes:

1. All concentrations in milligrams per liter (mg/l).
2. Data collected between 2004 and 2016.
3. Mean concentration includes average of detects and non-detects. Non-detects reported at the reporting limit (RL). If all results are non-detect, the maximum RL is shown for the mean.
4. Bolded numbers indicate that the concentration exceeds the Maximum Contaminant Level (MCL); for arsenic = 0.01 mg/L, cadmium = 0.005 mg/L, and selenium = 0.05 mg/L.

TABLE 2-2 MEASURED HYDRAULIC CONDUCTIVITIES IN ALLUVIAL AQUIFER WELLS AT BALLARD AND ADJACENT P4 SITES			
	Estimated Hydraulic Conductivity		
Location	(ft/day)	(cm/sec)	Mine
MW-15A	0.4	1×10^{-4}	Ballard
MW-16A	0.6	2×10^{-4}	Ballard
MMW017	0.6	2×10^{-4}	Ballard
MBW006	20	6×10^{-3}	Ballard
MBW009	0.7	2×10^{-4}	Ballard
MBW011	1	5×10^{-4}	Ballard
MBW027	2	6×10^{-4}	Ballard
MBW028	0.6	2×10^{-4}	Ballard
MMW014	2	6×10^{-4}	Henry
MBW085	2	5×10^{-4}	Enoch Valley
MBW087	6	2×10^{-3}	Enoch Valley

On the Ballard Site, the hydraulic conductivities of the monitored water-producing beds range from 0.4 to 20 ft/day (1×10^{-4} to 6×10^{-3} cm/sec). While not specifically tested, basic hydrogeologic understanding indicates that the intervening clay and silt beds will have hydraulic conductivities orders of magnitude lower, and therefore, the most rapid contaminant transport will occur in the monitored coarser-grained beds. However, the clay-rich beds are important in that they may have greater absorptive capacity.

Alluvial aquifer recharge is by direct precipitation and groundwater flow is from the topographic high points (i.e., ridges) to the low areas of adjacent valleys, which generally coincide with stream channels and rivers. On the east side of the Site, the alluvial aquifer also is recharged from the underlying Dinwoody Formation, which has higher potentiometric head. This results in an upward hydraulic gradient in the area and several springs are present where groundwater is directed to the surface. The stratigraphic packages of alternating beds of clays, silts, sands, and gravels in the alluvium often results in the occurrence of semi-confined conditions (e.g., often the hydraulic head associated with a sand or gravel layer will be above an overlying clay layer). In addition, it is observed that the bulk of contaminant transport may occur in one or a few thin higher permeability layers (e.g., sandy or gravelly units).

This same sedimentary layering also helps inhibit the vertical migration of potential contaminants by preferentially moving groundwater horizontally in higher permeability layers while inhibiting the downward migration into fine-grained lenses of silts and clays.

The aquifer directly beneath hillsides of the Site largely consists of colluvium that ranges in thickness from "not present" to approximately 10 feet thick. Within the mined area, most of this colluvium is either covered by waste rock, has been removed, or is otherwise disturbed. In the valleys to the west and east of the Site, the aquifer consists of mostly alluvium with an intermixed colluvial material from the adjacent hillslopes and can be approximately 150 feet thick or more.

In the upland areas beneath the Site, the colluvium thickness and groundwater flow within the alluvial unit is influenced by the Site topography. Prior to mining, the surface flow and groundwater flow were focused in the swales and gullies leading off the ridge. Post mining, the surface water flow has been disrupted over most of the Site, but the groundwater flow is still funneled to the gullies, which are now mostly buried by waste rock. This has resulted in several reasonably well-defined selenium plumes emanating from the southwestern and southeastern portions of the Site that generally coincide with pre-mining surface water channels (**Drawings 2-6** and **2-7**).

As noted, the shallow alluvial groundwater plumes generally coincide with the surface water channels, so another important feature is that the alluvial groundwater systems may interact directly with the local surface water systems in the valleys with gaining and losing streams at different locations. Therefore, not only are surface water channels an indicator of the preferred groundwater flow paths from the Site, but selenium contamination is also often coincident with both media being affected in the same areas near the Ballard Mine.

Wells Formation Aquifer. The Wells Formation aquifer is most accessible on the west side of the Site, where COC contamination is known in the vicinity of the West Ballard Pit (MMP035). The West Ballard Pit receives seep and spring discharges with elevated COCs from an uphill waste rock area. The discharge from these seeps and a spring infiltrates into the Wells Formation in the bottom of the mine pit, and consequently, the Wells Formation has definite measurable sources in this area.

Additional factors considered during the Ballard Mine RI of the Wells Formation included:

- The large undisturbed uphill bedrock exposures are primarily recharge areas for this aquifer locally.
- The depth to water in the formation generally increases with increased elevation at the Site.

Therefore, the RI tended to focus on investigation of the Wells Formation on the lower west side of the Site. This was because on the west side, groundwater could be reached at a reasonable depth, and it was presumed that a component of the hydraulic gradient is from the higher recharge areas toward the lower exposures exists. The lower areas on the opposite, eastern side of the Site, are dominated by the Dinwoody Formation, and the Wells Formation is present at depth below the Dinwoody Formation and the Phosphoria Formation (**Drawing 2-3**).

Five monitoring wells were installed in the Wells Formation in proximity to the West Ballard Mine pit - MMW001, MMW002, MMW006, MMW020, MMW021, with MMW001 and MMW002 being replaced by MMW020 and MMW021, respectively. Monitoring wells MMW001 and MMW002 were replaced because of excessive turbidity due to well construction. In addition, two monitoring wells, MMW030 and MMW031, were installed in the Wells Formation in the southwest and northwest portions of the Site, respectively, to address potential groundwater and COC transport off-Site in those directions.

In considering the Wells Formation, the geological and physical configuration of the aquifer is an important factor when discussing its potential attenuation characteristics. The unit consists of alternating beds of limestone and calcareous sandstone beds, and only locally one or two of the uppermost beds may be directly impacted by selenium concentrations that exceed its PCL. These beds are the units exposed in the mine pits adjacent to the Meade Peak Member ore unit. Locating these beds can be a challenge for well installation within the structurally complex geologic setting of the Ballard Site.

Within the Site, these beds are fractured and displaced by faulting and folding, and except for the beds exposed at the highest, north-central portion of the Site, they are truncated by faulting in the direction of bedding strike (**Drawing 2-3**). In addition, because the geology is locally steeply dipping, the top of the Wells Formation is often located at considerable depth beneath the Site. These factors isolate and compartmentalize the Wells Formation and make direct investigation (and hence remediation) difficult and costly. However, that segmentation/compartmentalization of the Wells Formation also keeps the contamination limited and local.

Examples of how the faulting and bedding compartmentalizes the Site is provided in the cross-sections depicted on **Drawing 2-4**. Both faulting and folding can and do position high permeability beds of the Site's sedimentary units against lower permeability beds. In addition, along the fault slip planes, fault gouge also can create low permeability barriers, or in some instances high permeability conduits. The faults that create conduits can be locations of enhanced recharge from the surface or adjoining fault blocks, therefore, creating areas of higher hydraulic head along and adjacent to the faults. This elevated hydraulic head can then act as flow barriers. This has been observed along the southwest portion of the Site at MMW030 in the Wells Formation. The converse also can be true where a fault acts as a drain.

The hydraulic conductivity of the water-bearing beds in the Wells Formation is relatively high. Three Wells Formation monitoring wells have been slug tested at the Ballard Site, MMW006, MMW021, and MMW031 (**Drawing 2-8**), with measured hydraulic conductivities of 3.5, 3.9, 10 ft/day, respectively (1.2×10^{-3}, 1.4×10^{-3}, and 4×10^{-3} cm/sec). However, because the continuity of bedding at the Site is disrupted by frequent faulting and folding, the relationship between the hydraulic conductivity and contaminant transport may not be direct or obvious (i.e., groundwater flow is cut off or redirected by faults and folding, and transport velocities may be controlled by lower permeability structural features).

2.1.5 Location and Dimensions of Site Plumes

Alluvial Aquifer. The alluvial groundwater selenium data and the extent of the alluvial selenium plumes are shown on **Drawings 2-6** and **2-7.** The plume locations roughly coincide with the surface water drainages and swales, where present. On the east side of the Site (**Drawing 2-6**), three plumes have been identified. The southern two plumes are confined to narrow drainages initially, before laterally expanding into the Wooley Valley alluvium. The northern of the three plumes is broader near the source because the percolation from the associated dump is not confined to a local drainage, but enters the valley alluvium directly from the waste rock dump. The length of this plume from the source edge to the PCL contour is approximately 800 feet with a maximum width of approximately 1,200 feet. Similarly measured, the longest, center plume has a length of approximately 1,600 feet, but a maximum width of only approximately 400 feet. The third plume is intermediate in size.

On the west side of the Site, there also are three distinct plumes (**Drawing 2-7**). The northern-most plume broadly emerges from the source area and is approximately 2,800 feet wide by 1,000 feet long in the maximum dimensions inside the PCL contour. The shape of this plume is dictated by the lack of a defined drainage in the extreme headwater area of Long Valley Creek. The other two plumes are located south of a flat hydrologic divide and flow toward the Blackfoot River. The center plume is similar to the northern plume in that it enters the valley alluvium across a broad front related to the waste rock source area, but then necks down as it flows toward the Blackfoot River. This is the largest plume at the Site with an axial length of approximately 5,200 feet and a width of approximately 2,200 feet.. The southernmost plume on the west side of the Site is largely confined to a narrow drainage swale and is the smallest of the three plumes on the west side.

Wells Formation Aquifer. The plume characteristics are more difficult to define in the Wells Formation because of the aforementioned geologic complexity. Reviewing the COC data for the Wells Formation aquifer around the West Ballard Pit supports that the contamination is stagnant or that COC transport is limited/local to near the Site. At the Site's West Ballard Pit, a distinct source of COC inflow from nearby seeps/springs is clearly present that has a direct effect on groundwater quality. The selenium data presented in the *Ballard RI Report* are summarized on **Drawing 2-8**, with the temporal trends in selenium concentrations discussed in more detail in Section 3.2.2.

What is known about selenium contamination in the Wells Formation, is that it is centered on the West Ballard Pit, which is consistent with a known seep/spring inflow source of contamination that discharges to the mine pit near MMW020 (refer to **Drawing 2-8**). Monitoring well MMW020 most directly displays the effects of this contamination source, and the introduction of COCs through infiltration into the Wells Formation.

There are two other affected wells located around the West Ballard Pit. MMW021 is across the mine pit (i.e., to the west of MMW020), and MMW006 is located at the south end of the mine pit. The variation in contamination detected in MMW020 is correlated with changes in annual precipitation, which results in changes of loading from the seeps and spring to the mine pit. Changes in concentrations in MMW006 and MMW021 are much more muted with only possible longer-term changes related to annual precipitation trends being observed.

Two additional monitoring wells were installed in the Wells Formation later in the RI characterization process (i.e., MMW030 and MMW031). These are peripheral to the West Ballard Pit, and are in the northwest and southwest corners of the Site (**Drawing 2-8**). These monitoring wells were located specifically to address possible off-Site flow paths in the Wells Formation from the West Ballard Pit.

The drilling and elevated piezometric data collected support that MMW030 is influenced by a fault that could be a Wells Formation recharge source or a local flow barrier that creates a large potentiometric gradient across the feature. The presence of this fault along the southwestern side of the Site provides evidence of a northerly direction of regional groundwater flow toward Henry Springs as discussed in Section 2.2, below. Both MMW030 and MMW031 exhibit background selenium concentrations and indicate that selenium contamination in the Wells Formation aquifer has not migrated to the southwest or northwest. Within the shallow portion of the aquifer, this combined with the geologic and topographic configuration of the Site support that impacted groundwater within the Wells Formation is largely confined to the Site near the West Ballard Pit and the seep and spring source.

2.2 DESCRIPTION OF POTENTIAL RECEPTORS

Potential activities such as grazing on P4 private lands and recreational activities (hunting, camping, and hiking) on the Ballard Site former State-leased lands are most representative of the current and possible future land uses possible on the Ballard Mine. Although unlikely, hypothetical future residents on the Ballard Mine are considered receptors in addition to current/future seasonal ranchers and recreational receptors as documented in the *Ballard BRA,* which is included as Appendix A to the *Ballard RI Report.*

The *Ballard BRA* evaluated receptor-specific human health risk and hazard estimates to hypothetical future residents and current/future seasonal ranchers based on exposure to impacted groundwater at the Site. Exposure to groundwater was not evaluated for recreational receptors as it is not considered a complete exposure pathway.

On the Ballard Mine proper, it is highly unlikely that a seasonal receptor would install a potable supply well on P4 privately-held or former State-leased lands. A more likely scenario is that seasonal receptors would bring drinking water from off-Site during their occasional Site visits. In addition, installation of domestic wells by hypothetical future residents will be prevented using institutional controls (ICs) as discussed in Section 2.3.

Away from the Ballard Mine area, there are no known shallow alluvial domestic wells that are close enough to the Ballard Mine to be a pathway to potential human receptors. The alluvial groundwater is not considered a good water source as a result of the shallow depth and lower yields. Most of the Site's alluvial groundwater plumes are located on former State-leased lands or P4 private property and where they are not, P4 is pursuing land purchase or land exchanges in order to control the beneficial use of these areas. As a result, there are no current users and there would be no anticipated future users (with ICs in place) of the mine-affected shallow alluvial groundwater.

No industrial, domestic, or agricultural wells are known to be installed in the Wells Formation in the vicinity of the Site, often because of the depth and difficulty of drilling and locating permeable beds within the Wells Formation. In addition, the natural water quality in the Wells Formation is not desirable as potable water, because it often has high dissolved solids and a sulfur odor (P4 personal communication, 2017). It is notable that most of the unimpacted and background Wells Formation monitoring wells sampled as part of the Ballard, Henry, and Enoch Valley RIs have had elevated concentrations of iron, manganese, and aluminum that often exceed the Secondary MCLs. As presented in the *Ballard RI Report*, the nearest location for Wells Formation groundwater discharge where environmental receptors could be affected is the Henry Springs located 5.5 miles from the Ballard Site. Discharge from these springs is derived from the Wells Formation, and has been dated to between 10,000 and 20,000 years old. These springs are unimpacted based on historical sampling results. Currently, impacted groundwater in the Wells Formation at the Ballard Site is unlikely to reach any receptors.

There is one complete exposure pathway identified in the *Ballard BRA,* where mine-affected shallow groundwater discharges and becomes surface water (i.e., at the seeps/springs located near the margins of the waste rock dumps, and possibly where a plume intersects the Blackfoot River). This completed pathway could present risks to current and future land users and this risk will be addressed in the RA as further discussed in Section 2.3 below.

2.3 COMPONENTS OF PROPOSED SITE-WIDE RA

The proposed remedy for the Ballard Site groundwater includes a combination of permeable reactive barriers (PRBs), MNA, and ICs for mine-influenced groundwater, in conjunction with source controls in the upland soil/waste rock. MNA will be used as a polishing step to address contamination that has already been released to shallow groundwater, while source controls and PRBs will be used to mitigate future releases, and ICs will be used to prevent groundwater use while MNA is underway and until groundwater cleanup levels are achieved. MNA for the Ballard Mine groundwater would rely on several mechanisms for attenuation of COCs, including physical and biochemical processes (e.g., dilution and dispersion, sorption, and biological reduction) as discussed in Section 3.0. It is anticipated that biological reduction, currently supported by limited data, would primarily occur near the source areas and along the Blackfoot River corridor. LTM would be conducted at strategic sampling locations in all groundwater contaminant plumes to track progress toward meeting cleanup levels.

The components of the Site-wide RA work together to facilitate the overall remediation of the Site with MNA working as a polishing step to address residual COCs in the groundwater system that would otherwise be difficult to remediate. The physical components and general order of implementation are shown on **Drawing 2-9**. From a regulatory and technical perspective, MNA is not a viable alternative if an ongoing source is present. In addition, because MNA may take longer to remediate a groundwater plume, measures should be in place to mitigate the potential risk to any potential receptors. The preferred Site-wide remedy includes components to address these risks as presented in *Ballard FS Memorandums #1 and #2*, and as summarized below with specific emphasis on their relationship to groundwater MNA.

2.3.1 Institutional Controls (ICs)

As described above in Section 2.2, there are no current uses of groundwater in the COC-affected areas for domestic potable water. ICs would be implemented to prevent future use until the plumes are remediated. ICs are administrative actions to limit human exposures. Propriety control ICs are used to track changes in land use or ownership (i.e., deed restrictions), and develop a notification system to ensure current and potential future owners are aware of possible exposure hazards on the subject property.

The ICs would be implemented throughout the areas of the shallow (alluvial) and deep (Wells Formation) aquifers known to be affected by concentrations of COCs exceeding PCLs. The ICs will focus on preventing groundwater extraction for areas affected by COC concentrations greater than the PCLs.

For the alluvial aquifer, the ICs would need to be implemented on land owned by P4, the State of Idaho, and other private parties, primarily west of the Site. **Drawing 2-5** includes the known boundaries of selenium plumes in the alluvial aquifer and surface property ownership. Because of the limited definable plume in the Wells Formation and the difficulty in drilling to the COC-affected Wells Formation units, the ICs for the Wells Formation would be limited to the P4 privately-owned property and State lands. Through the implementation of ICs, there would be a high level of assurance that the risk to potential human receptors from groundwater consumption would be removed. This is in large part because any such use would be a new use requiring a new well and associated State permit.

2.3.2 Upland Soil/Waste Rock Remedy Components – Source Controls

Source controls are a key technical and regulatory requirement for the use of MNA as a remedy component for Site groundwater. Without source controls, the natural attenuation capacity of the aquifers may be overwhelmed by the influx of COCs. The proposed RA includes sequential grading, consolidating, and covering the mine-affected upland soil/waste rock to minimize environmental exposures, which would be implemented in conjunction with a phased recovery of incidental phosphate ore. Remedial activities would include moving portions of the existing waste rock dumps, in addition to the waste rock created while recovering ore, to backfilling the existing and new open pits to create favorable site grades and control stormwater runoff and erosion. The resulting graded surfaces would be contoured with the surrounding natural surfaces and would be capped with an evapotranspiration (ET) cover system that is designed to shed or otherwise store and evapotranspire water before it infiltrates into and through the underlying waste rock (**Drawing 2-9**).

The ET cover system would be vegetated with native plant species that are selected to control erosion and to transpire moisture out of the cover materials, while not tapping into the underlying waste rock. The vegetated ET cover would reduce precipitation infiltration into the underlying waste rock (thereby reducing transport of mine-related COCs to the underlying groundwater and seeps/springs at the edges of the existing waste rock).

The effect of the upland soil/waste rock alternative would be to reduce the contact of incidental precipitation with waste rock and exposed in-situ materials that are the source for the groundwater plumes observed at the Site. As documented in the *Cover System Evaluation Memorandum* (MWH, 2017b), MWH/Stantec reviewed inputs and conclusions that are detailed in Golder Associates' (Golder's) cover design modeling effort (Golder, 2015) for the Ballard Site. MWH/Stantec reviewed this modeling effort to evaluate if this modeling effort is reasonable/defendable, and if it could be used to select the most appropriate cover for use in the Ballard FS. Golder's model inputs include: the climate data evaluated and selected for the Ballard cover modeling (and how climate change might affect it), material properties, and vegetative cover selection. Golder performed infiltration modeling for 13 different soil cover systems on various slope aspects under seven unique configurations.

Golder's model results varied significantly among the various cover systems with 100-year average annual net infiltration rates ranging from the low of <0.001 inches per year (in/yr) for a geosynthetic clay laminated liner (GCLL) system to a high of 11.1 in/yr for exposed chert waste rock. ET covers had average infiltration rates ranging from 3.1 in/yr to 0.78 in/yr. Golder's analysis showed the GCLL and three different (e.g., various thicknesses and material properties) ET cover systems reduced infiltration below 1.24 in/yr on average.

Although average annual conditions are important to the selection of cover designs, repeating wet years should also be evaluated for potential extreme infiltration loading conditions. For the wettest 5-year period of the 100-year record, the model results for south-, west-, and east-facing slopes showed consistent results of GCLL and ET cover systems reducing infiltration below 1.24 in/yr with only the GCLL reducing percolation below 1.24 in/yr on north-facing slopes (Golder, 2015).

From these results, the technical analyses were based on an ET cover system consisting of a 5-foot thick monolithic medium-textured alluvium overlying waste rock of either chert or shale. Golder's modeling showed this cover produced the best results for average infiltration rates, and medium-textured alluvial material is available near the Site. It is found in large enough quantities to supply the construction requirements of the cover system. Although the ET cover did not perform as well as the GCLL in modeling results, the cover materials are native and have a potentially infinite life cycle, whereas GCLL performance may falter over the longer term.

The proposed ET cover system is estimated to produce annual average infiltration rates of 0.78 in/yr or less (an approximately 13-fold reduction in infiltration compared to the current conditions with exposed waste rock). The cover system performance criteria will be further evaluated during the RD.

It is noted that the proposed upland soil/waste rock remedy is not an instantaneous form of source control. Residual impacted pore water needs to drain from the waste rock before the groundwater COC source is significantly reduced. This drain down is typically asymptotic, and because of the large variation in pile size and waste rock geotechnical composition, the rate of COC flux from the waste rock will vary across the Site. In addition, the remediation of individual waste rocks dumps and backfilled pits will be phased during the RA. It is proposed that remediation will begin on the east side of the Site and will require six to eight years to complete over the entire Site. Therefore, time for source control to become effective is difficult to determine. Other components of the remedy elements as discussed below will address other contaminated media in the short-term, until the positive effects of the upland soil/waste rock remediation (i.e., source control) are realized in groundwater and other associated media.

2.3.3 Surface Water and Groundwater Remedy Components

Primarily because the exposure to COCs in groundwater discharging to surface water results in an ecological and human health risk, the groundwater upgradient of these surface expressions of groundwater (i.e., seeps and springs) will be treated in situ as part of the proposed RA. This treatment will consist of the installation of PRBs and engineered wetlands as described in *Ballard FS Memorandum #2* and shown conceptually on **Drawing 2-9**.

While the focus of this action is to reduce concentrations of COCs in groundwater to acceptable levels in the discharge to surface water, many of the PRBs/wetlands installed to treat seep/spring locations are in the core of the Site groundwater plumes. Therefore, while the intent of the PRBs is not to directly treat entire alluvial groundwater plumes emanating from the upland source area, the reduction in COCs due to where the PRBs are installed, will significantly reduce transport of COCs into the alluvial plumes that are moving away from the source area (**Drawings 2-5** and **2-9**). Therefore, the PRBs will help facilitate MNA effectiveness early in the RA, by reducing COC flux during the period between PRB installation up to the end of the upland soil/waste rock remedy (grading, consolidation, backfilling and installation of the ET cover system) and prior to substantial waste rock drain down (as discussed above).

It is believed that this cleanup near the cover margin, when combined with the infiltration of clean stormwater/snow melt runoff from the covered surfaces, will reduce concentrations of COCs in the shallow alluvial aquifer to below the MCLs. Cleanup will occur first near the margins of the cover and then expand in a downgradient direction through infiltration of unimpacted meteoric water and natural attenuation including sorption, dilution, and dispersion. The PRBs/wetlands would be maintained and evaluated via LTM until: 1) the seeps/springs dry up as a result of the cover systems installed in the upland soil/waste rock areas, or 2) PCLs are consistently achieved in the groundwater upgradient of the PRBs.

2.3.4 MNA Remedy Component

As presented in this *MNA Memo*, the proposed overall Site remedy includes natural attenuation processes to reduce COC concentrations in distal portions of the alluvial groundwater plumes and in the Wells Formation (i.e., MNA). For MNA to be successful, source controls, as outlined above, must be implemented in the source areas (i.e., upland soil/waste rock) to significantly reduce the flux of COCs to groundwater. Source controls will result in changing hydrologic and geochemical

Site conditions (compared to current conditions) as discussed in Section 3.0, which will enhance the effectiveness of MNA as a polishing component of the groundwater remedy. This alternative also would require aforementioned ICs to restrict groundwater use until cleanup levels are achieved.

Evaluation of the MNA alternative in conjunction with PRBs, ICs, and LUCs in the *Ballard FS Memo #2* ranked the proposed alternative moderate to high for all seven criteria detailed in the FS and provides the following advantages:

- Groundwater would be treated at the seep/spring locations using PRBs where the greatest concentration of COCs are present and where there is a potential for exposures to human and ecological receptors. PRBs also will reduce the transport of COCs into the shallow groundwater alluvial plumes.
- Relatively low design, construction, O&M, and decommissioning costs (including treatment media disposal).
- In-situ treatment and little to no treatment residuals.

2.4 REGULATORY BASIS FOR MNA SELECTION

MNA is an USEPA-recognized limited action response that relies on natural attenuation processes to meet the remediation goals for a Site (USEPA - 1999, 2007a, 2007b, and 2015). USEPA presents the rationale and requirements for characterization and implementation in these documents.

USEPA defines MNA as:

"*The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The 'natural attenuation processes' that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants (USEPA, 1999).*"

In the case of the inorganic COCs at the Site, the attenuation processes would be sorption to the aquifer matrix, biological reduction, as well as dilution and dispersion. Dilution and dispersion generally are not appropriate as primary MNA mechanisms because they reduce concentrations through dispersal of contaminant mass rather than destruction or immobilization of contaminant mass. Dilution and dispersion may be appropriate as a "polishing step" for distal portions of a plume when an active remedy is being used at a site, source control is complete and appropriate land use and groundwater use controls are in place [emphasis in original] (USEPA, 2015).

MNA must achieve remedial action objective (RAOs) within a reasonable time frame (USEPA, 2015). At the Ballard Site, for MNA to meet remediation goals in a realistic timeframe, source control needs to be a key component of the overall remedy. As explained above (Section 2.3), source control of the existing Site waste rock dumps is a key component of the preferred remedy. This will significantly reduce contaminant migration from the waste rock to the groundwater. In addition, active groundwater remedy components will be installed at the margin of the covered waste rock piles to treat the high concentration portions of groundwater plumes using PRBs. These will be designed to reduce contaminant concentrations to below regulatory levels in water flowing from the PRBs. The effect of these active remedy components will be to significantly reduce contamination currently migrating in the groundwater from the source areas, and will improve hydrologic and geochemical conditions allowing for MNA to be an effective component of the groundwater remedy. Natural attenuation will address the residual groundwater plumes that remain following implementation of these remedy components, with the overall effect of achieving groundwater standards at the points of compliance (POC) downgradient of the source areas.

Institutional Controls (ICs) typically are used where MNA is part of the selected Site remedy to restrict access to Site groundwater and exposure to possible receptors. The Ballard Site will require ICs to restrict groundwater access/use until RAOs are achieved.

Long-term performance monitoring (LTM) also is a fundamental component of MNA to monitor progress in achieving RAOs. At the Ballard Site, LTM will be used to evaluate the natural attenuation processes and its progress in meeting the longer-term RAOs. Use of MNA as a remedy component requires collection and analysis of data, as part of the LTM program, to evaluate and demonstrate MNA performance.

MNA Performance Evaluation. The 1999 MNA guidance (USEPA, 1999) recommends a tiered-approach to develop multiple lines of evidence for evaluation of MNA. The 2015 guidance (USEPA, 2015) revised this approach for evaluating MNA of inorganic constituents via the following four phases:

- Phase I: Demonstration that the groundwater plume is *not expanding*.[1]
- Phase II: Determination that the *mechanism and rate* of the attenuation process are sufficient.[2]
- Phase III: Determination that the *capacity* of the aquifer is sufficient to attenuate the mass of contaminant within the plume and the *stability* of the immobilized contaminant is sufficient to resist re-mobilization.[3]
- Phase IV: Design of a *performance monitoring program* based on an understanding of the mechanism of the attenuation process, and establishment of contingency remedies tailored to site-specific characteristics. This phase in effect reflects recommendations in the 1999 MNA guidance, but consolidated into a single, additional phase.

This tiered-approach will be developed for the Site as presented in Sections 3.0 and 4.0.

As a polishing component of the overall Site remedy, USEPA recognizes that MNA offers the following advantages (USEPA, 1999):

- Contaminants remain in-situ reducing potential human health and environmental exposures.
- The remedy is passive generating no secondary waste such as ex-situ water treatment.
- MNA can be broadly applied to groundwater plumes throughout the Site except where it is treated near source areas/plume centers.
- Minimal surface disturbance, permitting and staffing requirement when compared to active remedies.
- Relatively low cost.

In some situations, active treatment of a whole plume may be technically difficult or even impracticable, which is the case at the Ballard Site. As such, MNA provides an alternative method for achieving Site remediation in a controlled manner throughout the Site.

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[1] In the 1999 MNA guidance, this tier is described as: "Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. (In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration**. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood**.)" (emphasis added)

[2] In the 1999 MNA guidance, this tier is described as: "Hydrogeologic and geochemical data that can be used to demonstrate **indirectly** the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels. For example, characterization data may be used to quantify the rates of contaminant sorption, dilution, or volatilization, or to demonstrate and quantify the rates of biological degradation processes occurring at the site." (emphasis in original).

[3] In the 1999 MNA guidance, this tier is described as: "Data from field or microcosm studies (conducted in or with actual contaminated site media) which **directly** demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only)." (emphasis in original).

USEPA also recognizes that MNA has these limitations:

- Longer cleanup timeframes.
- Additional site characterization may be required to support MNA.
- Expanded Site monitoring program (extent and duration).
- Cross media transfer of COCs – sorption to the aquifer matrix.
- Public acceptance of MNA may need expanded explanation and education.
- May require a contingency or backup plan should MNA fail.

Key considerations when considering the suitability of MNA as a remedy component (USEPA, 2015) include:

- Whether contaminants are likely to be effectively addressed by natural attenuation processes.
- The stability of the groundwater contaminant plume and its potential for further migration.
- The aquifer hydrologic characteristics (permeability, porosity, and other related characteristics).
- The potential for unacceptable risks to human health or environmental resources by the contamination (considering potential use of contaminated groundwater, e.g., domestic supply or agricultural).

MNA should not be used where the remedy would result in either plume migration or impacts to human health or environmental resources. Therefore, MNA may be an appropriate candidate for a remedy if the contaminant plumes are no longer increasing in extent, or are shrinking (USEPA, 2015). Obviously, groundwater restoration is more likely to occur and in a shorter time frame if source controls are implemented, which is the case for the Ballard Site groundwater plumes. Please refer to Section 3.0 for a discussion of the technical basis for the selection of the MNA as a polishing component of the Ballard Site remedy for groundwater.

3 TECHNICAL BASIS FOR MNA

The technical basis for selection of MNA as a polishing step for cleanup of contaminated groundwater at the Ballard Site is described in this section. Specifically, the MNA mechanisms that are present at the Site and that will be effective for managing and reducing plumes are discussed in Section 3.1. In Section 3.2, the existing Site data that support the viability of MNA for Site groundwater is presented and discussed. Finally, in Section 3.3 the components of Sections 2.0 and 3.0 are summarized to describe how MNA will work with the other remedy components to remediate Site groundwater within the regulatory and physical/temporal framework.

3.1 ATTENUATION MECHANISMS AT THE SITE

As quoted previously in Section 2.4, the USEPA definition of MNA includes several natural attenuation mechanisms. They further define these processes as in-situ processes that include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants (USEPA, 1999). For the Ballard Site, the processes can be generally defined as physical (dispersion and dilution) and biochemical (chemical attenuation/sorption and biological reduction).

3.1.1 Physical Processes

The physical processes of dispersion and dilution at the Site will be important for the attenuation of the groundwater plumes. Dispersion is the process where a mass of COCs disperses, and to some extent diffuses, into a larger volume of water with lower concentrations, thus reducing the overall mass of COCs per unit volume (i.e., reducing the concentration). Presented in terms of the Site conditions, both lateral and longitudinal dispersion are and will be important at the Site. Plume constraints or lack of constraints in movement are especially notable where the alluvial plumes move out into the alluvial valleys. Once the plumes have moved away from the source areas, they are less constrained by alluvial channels. This physical process will not be significantly altered by the remedial actions. Except that once the source areas are covered and the alluvial plumes are not being continually augmented with source area contaminants, the dispersion process will be more effective in reducing plume concentration.

Dilution is the addition of water with lower COC concentrations to a volume of water with higher COC concentrations, and thereby, reducing the overall mass of COCs per unit volume. At the Site, surface water and alluvial groundwater are closely related with both groundwater discharging to surface water, and surface water infiltrating to groundwater; the latter process dominates for most of the year. Dilution in the shallow alluvial aquifer largely will occur from unimpacted surface water running off the cover systems then infiltrating, and surface water infiltration downgradient of the source areas (i.e., precipitation and intermittent streams). Though more difficult to define (because of large surface exposures of Wells Formation north of the Site) dilution from recharge also is expected to be significant in the Wells Formation. In addition to the surface water as a dilution mechanism, PRBs also will provide a source of dilution into the upgradient portions of the plumes (at the cover margins), effectively helping to attenuate the portions of the alluvial plumes with the highest concentrations. The PRBs may also contribute to biochemical attenuation as further discussed below.

3.1.2. Biochemical Processes

The biological and chemical processes that are important at the Site are closely linked and are therefore considered together. This is because the two common mobile forms of selenium (the primary COC in groundwater relative to MNA) are selenite [Se^{+4}] and selenate [Se^{+6}]. Of these forms of selenium, selenate is more mobile and less susceptible to chemical attenuation processes than is selenite. Most of the selenium emanating from the Site source areas is selenate. Chemical attenuation downgradient of the sources is most effective if selenate is reduced to selenite. This process can directly immobilize selenium if the reduction proceeds to elemental selenium [Se0], which will precipitate. (*Please note: A detailed discussion of selenium geochemistry and fate and transport is presented in the P4 Sites RI/FS Work Plan.*)

Within the natural setting of the Site, biological-mediated (microbial) reduction (e.g., of selenite) is the primary process responsible for selenium removal or attenuation (i.e., reduction in groundwater selenium concentrations). Biological-mediated reduction generally requires anaerobic conditions. However, as noted in Hay et al. (2016), conditions considered "suboxic" (approximately < 0.5 mg/L O_2) are sufficient for selenium reduction.

Once selenate is reduced to selenite, adsorption to mineral or organic surfaces is the primary attenuation process although some less important processes such as absorption, co-precipitation, and precipitation can occur (Alloway, 2013), as well as some selenate adsorption. Adsorption sites include organic materials, iron and manganese minerals, clays, and carbonates. Iron and manganese oxides and oxyhydroxides, present in the local aquifers, are especially favorable adsorption sites in the right geochemical conditions.

A key component needed for the growth of the required microbial communities is a supply of biodegradable organics. The following conditions favorable for biochemical selenium attenuation at the Site occur or are present:

1) Beneath wetlands areas, like along the Blackfoot River with its higher organics,
2) Within the Site waste rock because of the high organic content of the Meade Peak Member shales (Hay et al., 2016; Tetra Tech, 2008), and
3) Potentially within deeper portions of the Wells Formation due to less oxic conditions.

It is expected that attenuation within the waste rock source areas will increase once the dumps are reconfigured and covered due to a reduced influx of oxygen. Presently, oxygen flux through some coarse-grained, uncovered waste rock surfaces may be preventing the necessary suboxic conditions from developing in these upland source areas. The reduction of oxygenated water from the Site (that also carries other oxidants like ferric iron), also may help to develop reduced conditions in the aquifer, especially within the Wells Formation. The planned PRBs also will add reduced groundwater to the alluvial plumes.

There is some evidence that attenuation is occurring in localized areas of the Site, as presented in the following section. For example, some adsorption of selenate or selenite to iron and manganese oxides may be occurring along plume edges. Additional investigation of these areas during the pre-design study, as presented in Section 4.0, will help define the processes currently acting to attenuate selenium, and may suggest ways to optimize current attenuation processes.

3.2 DATA THAT SUPPORT ATTENUATION

3.2.1 Alluvial Aquifer Attenuation Evidence

In accordance with the USEPA's tiered-approach for MNA evaluations discussed in Section 2.4, the following discussion focuses on the Phase I evaluation, which looks at the Site groundwater data (i.e., contaminant concentrations/distribution and general groundwater chemistry) in evaluation of the alluvial aquifer's plume stability. Other future phases of the MNA evaluation are summarized in Section 4.1.

Phase I Plume Stability Evaluation. With few exceptions, concentrations of selenium in the alluvial aquifer appear relatively static and are not increasing over time as shown on **Figure 3-1** with the exception of two of the 16 shallow monitoring wells. The selenium concentrations in MBW032 have shown an increasing trend, but this well is located very near to the waste rock source near the core of an alluvial plume. MBW027 is in a similar position relative to the source area and plume; although, it is co-located with MMW017, which does not show a similar trend.

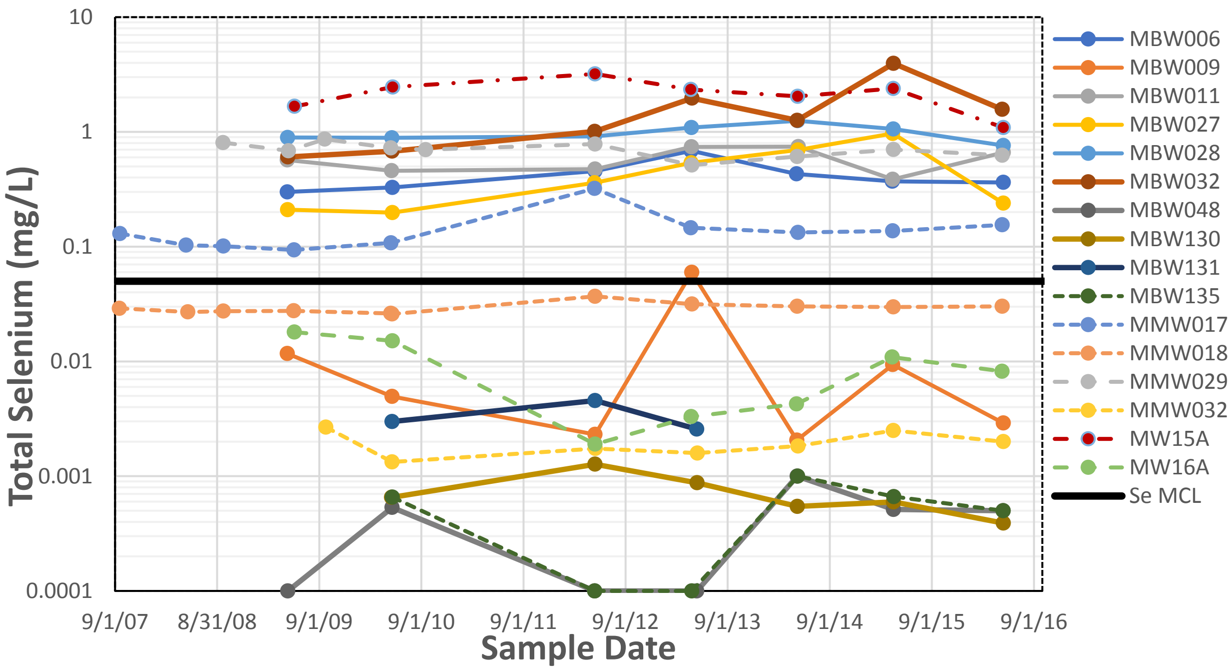

Figure 3-1. Plot of Total Selenium Concentrations Over Time in Alluvial Monitoring Wells

It should be noted that monitoring well MMW017 is screened at the bottom of the alluvium; whereas, MBW027 is screened in the shallower portion of the alluvial aquifer, and therefore, this suggests slightly differing responses in the plume vertically with the shallower groundwater being more reflective of short-term changes in source concentrations. Two monitoring wells, MBW048 and MBW130 are located in downgradient positions on the eastern side of the Site (**Drawing 2-6**). Neither of these monitoring wells have exhibited an increasing trend in selenium concentrations.

The selenium concentration data indicate relatively static or slowly advancing plumes. These data support the hypothesis of attenuation along the leading edges of the alluvial plumes. It is recognized that additional monitoring well locations are needed off the margins of the plumes to confirm that conditions are favorable for attenuation (along the edges of the various alluvial plumes). The alluvial plume edges were mostly defined during one-time grab sample events using direct-push borings in 2008, 2009, and 2010.

Evaluation of Se/SO4 Ratios. One method to assess if selenium attenuation is occurring in groundwater at phosphate mine sites is by evaluating selenium:sulfate ratios ($Se:SO_4$). Hay et al. (2016) presents empirical data supporting a graphical method for evaluating selenium attenuation using the selenium-sulfate relationship. Key to this method is the conclusion that if an observed reduction in concentration is due to dilution or dispersion, the $Se:SO_4$ will not significantly change, whereas if it is due to attenuation, selenium concentrations will decrease at a disproportionately greater rate than sulfate. While Hay et al. (2016) focused on the concept of using $Se:SO_4$ ratios for evaluating attenuation in waste rock, the concept is also valid for the groundwater collected from the Site's alluvial and Wells Formation aquifers. The Ballard Site alluvial groundwater selenium and sulfate groundwater concentrations are plotted against each other on **Figure 3-2**, along with the reference criteria and the bounding lines from Hay et al. (2016).

In Hay et al. (2016), it was observed that selenium and sulfate concentrations that both plotted in the range of results for unsaturated column leachates were generally indicative of low or no attenuation (i.e., between the solid red lines on **Figure 3-2**). However, groundwater concentrations lower in selenium relative to sulfate that plotted near the saturated column line (black solid line), were suggestive of selenium attenuation. The data for the Ballard Site alluvial groundwater largely plot within the range that suggest weak or no attenuation. The exceptions are data from monitoring wells MW-16A and MBW009, which suggest attenuation.

There are several possible reasons for this apparent lack of attenuation observed in the majority of monitoring wells. First, it is noted that the Hay et al. (2016) analysis was primarily focused on attenuation within waste rock dumps, and the suboxic conditions most favorable for the attenuation in dumps generally are apparently not present on the Ballard Site. Lower oxygen infiltration into the dump and/or a higher water content are most favorable for attenuation within the waste rock, and neither condition is prevalent in the Site's current mostly un-reclaimed configuration. Therefore, based on the data, pore water discharging from the waste rock to groundwater has $Se:SO_4$ ratios indicating the lack of attenuation in the waste rock environment. It is this pore water, which has mixed with the groundwater, that is largely monitored by the well network.

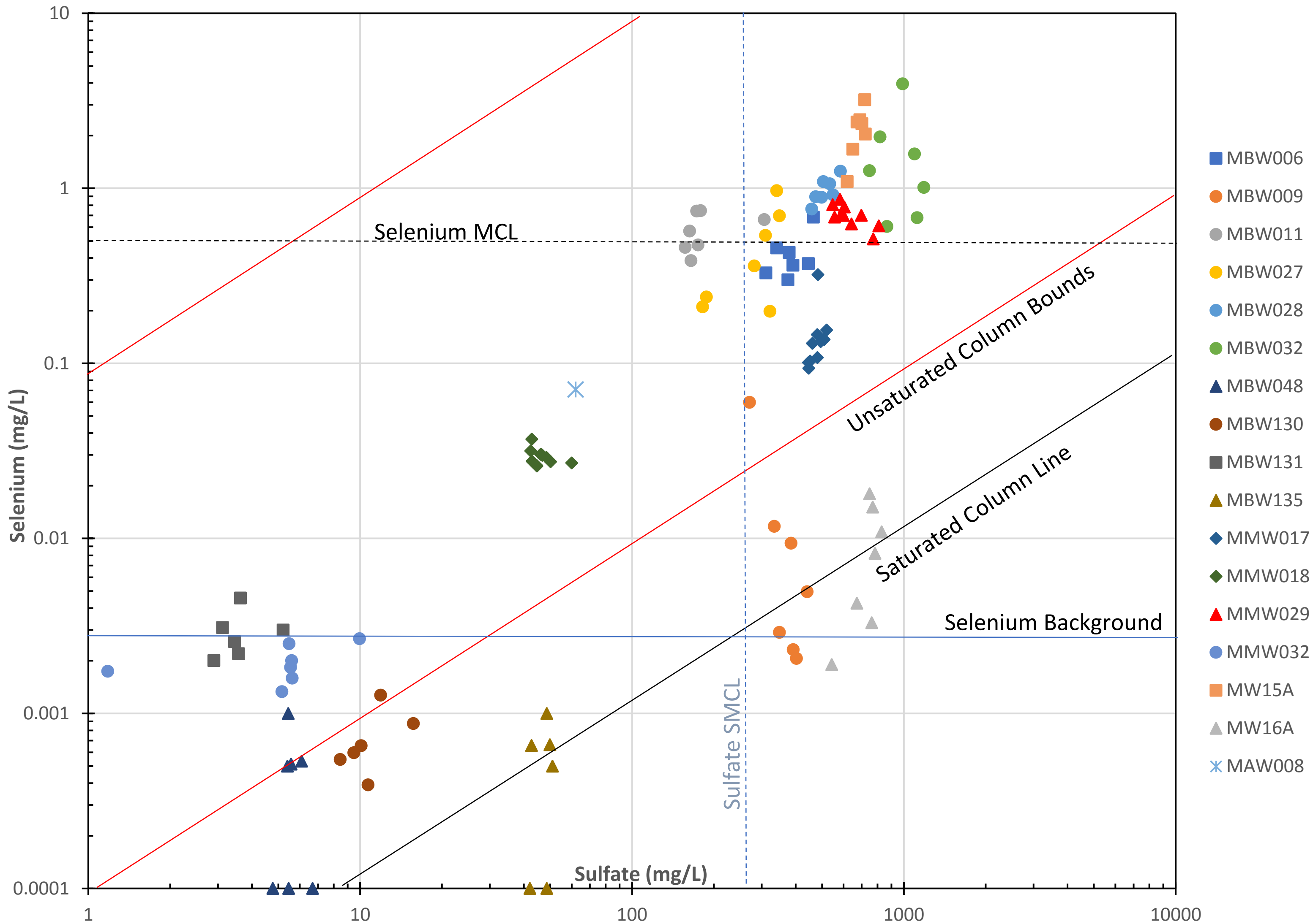

Figure 3-2. Plot of Total Selenium and Sulfate for Alluvial Monitoring Wells

(Note data collection from 2008 – 2016)

Another reason why attenuation is not observed in the Ballard Site alluvial groundwater samples is also due to monitoring well placement (as mentioned above). Most of the monitoring wells are placed in the core of the plumes close to the mine waste rock dumps where impacted water may have been flowing through the alluvium for more than 50 years. Therefore, the attenuation process may have been exhausted in the alluvial plume cores near the Site (e.g., organic carbon needed for biological reduction is limited in the alluvium and the carbon has been spent, and/or all mineral absorption sites have been filled). However, attenuation should still be active along the alluvial plume edges. The plume edges were largely defined using one-time grab sampling with direct-push borings, and these groundwater samples were only analyzed for selenium which limits the information available for MNA determinations from those borings.

It should be noted that monitoring wells MW-16A and MBW009 are in locations that appear to be near the edges of the alluvial plumes, and the $Se:SO_4$ ratios in groundwater from these locations suggest that attenuation is occurring.

Post-RA Conditions for MNA. It is noted that it will be more favorable for in-dump attenuation post-RA due to reduced oxygen influx to the waste rock resulting from the proposed ET cover system. Therefore, this is another way that source controls will help reduce selenium concentrations in the residual groundwater drain down following remediation including cover placement. Currently, in the unreclaimed waste rock dumps found at the Ballard Site, water and air infiltration is only limited by the waste rock particle size, which may be coarse in some areas, and variable vegetation coverage, ranging from non-existent to good. The addition of an engineered cover not only provides a more uniform fine-grained soil media overlying the waste rock that better holds water and helps reduce air flux into underlying the waste rock, but it also allows for healthy microbial communities to develop in the soil that consume oxygen. Limiting air flux in the waste rock encourages suboxic conditions that are very favorable for in-dump selenium attenuation (Hay et al., 2016).

Such attenuation is favored in the waste rock because of the high organic content of the Meade Peak Member of the Phosphoria that will be the primary dump material in the regraded and covered waste rock dumps at the Ballard Site. Low oxygen and elevated carbon dioxide observed in waste rock dumps, including at the Enoch Valley Mine, suggest such biological reduction occurs in favorably reclaimed waste rock (Tetra Tech, 2008). In addition, the passive removal of selenium in other mine settings has been demonstrated for a variety of environments characterized by saturated and suboxic conditions, including mine-influenced wetlands (Martin et al., 2011) and saturated backfills (Bianchin et al., 2013; Dockrey et al., 2014). In a recent study that assessed nitrate and selenium in mine drainages, evidence of selenium reduction and denitrification also was shown for unsaturated waste rock, suggesting suboxia and selenium bio-reduction can also occur within the unsaturated interiors of large-scale mine waste repositories (Dockrey et al., 2014).

Also, surface water running off the newly constructed caps will be unimpacted and will infiltrate and mix with groundwater of the alluvial aquifer, thereby reducing COC concentrations. Without an ongoing source of contamination and with the infiltration of unimpacted water from the upland areas at the Ballard Site, the mine-affected alluvial and Wells Formation groundwater will be diluted consistent with USEPA policy and will naturally attenuate over time, resulting in COC concentrations that do not pose unacceptable risks.

Chemical Properties Relevant to MNA. MW-16A exhibits some of the lowest dissolved oxygen (DO) and oxidation-reduction potential (ORP) measurements on the Site, possibly suggesting biological activity in the aquifer at that location. The DO for this well averages 0.50 mg/L and the ORP averages -44.4 millivolts. Additional alluvial groundwater sampling during pre-design studies along plume boundaries (as discussed in Section 4.0) and evaluation of $Se:SO_4$ ratios and DO and ORP measurements, as well as general water quality parameters (total organic carbon, ferrous/ferric iron, selenium species, and other trace metals/non-metals) will be useful in determining if selenium attenuation processes are active in the alluvial aquifer.

Blackfoot River – Southwestern Alluvial Plume Natural Attenuation. As described in the *Ballard RI Report*, and as shown on **Drawing 2-5**, an alluvial plume travels southwest from the source areas towards the Blackfoot River. As presented in the *Ballard RI Report*, no impacts to the river have been measured outside the range of measurement errors. The possible loading that has been measured is much smaller than would have been predicted based on the groundwater plume dimension and groundwater flow velocity. It may be that the selenium flux from groundwater to the Blackfoot River is too small to accurately quantify, but a viable alternate explanation also is possible.

Near the river, wetlands conditions are common, and these conditions can and often do result in attenuation of selenium. The Blackfoot River riparian corridor and the wetlands present at the margins of the river within the flood plain may act as a natural treatment system for selenium in groundwater. This natural system may act to reduce selenium loading to the river.

Currently, there has been no quantification or verification of this hypothesis, but an evaluation of this potential component of MNA are presented in the pre-design studies, as discussed in Section 4.0.

3.2.2 Wells Formation Aquifer Attenuation Evidence

In accordance with the USEPA's tiered-approach for MNA evaluations discussed in Section 2.4, the following discussion focuses on the Phase I evaluation, which looks at the Site's groundwater data (i.e., contaminant concentrations/distribution and general groundwater chemistry) in evaluation of the Wells Formation plume stability. Other future phases of the MNA evaluation are summarized in Section 4.1.

Phase I Evaluation. Selenium concentrations over time in the Wells Formation monitoring locations are provided graphically through the Spring 2016 and shown on **Figure 3-3**. What is apparent about selenium contamination in the Wells Formation is that near the contaminated seep/spring inflow sources, the selenium PCL is frequently exceeded. Monitoring well MMW020 is most directly associated with the contaminated seep and spring inflow to the bottom of the West Ballard Pit, and subsequent infiltration to the Wells Formation in the pit bottom. Winter precipitation for period October – April for the nearby Blackfoot Bridge Mine is provided on **Figure 3-3**, along with the total selenium concentrations. The winter precipitation and subsequent snow melt mostly affects the seep and spring flow, with higher precipitation resulting in greater seep and spring flow and thereby greater loading of the Wells Formation aquifer near the source.

The primary observation is that in low precipitation years, the selenium concentrations in MMW020 drop to near or below the selenium PCL (the MCL). Reasons for this are discussed in more detail below. It is noted that there is an apparent lagged response in MMW006 to the elevated concentrations seen in MMW020, and possibly a very muted response in MMW021. All three wells are directly adjacent to the West Ballard Pit (**Drawing 2-8**), but in a slightly different stratigraphic depth within the Wells Formation; therefore, transport across bedding appears to have occurred, but at relatively slow rates.

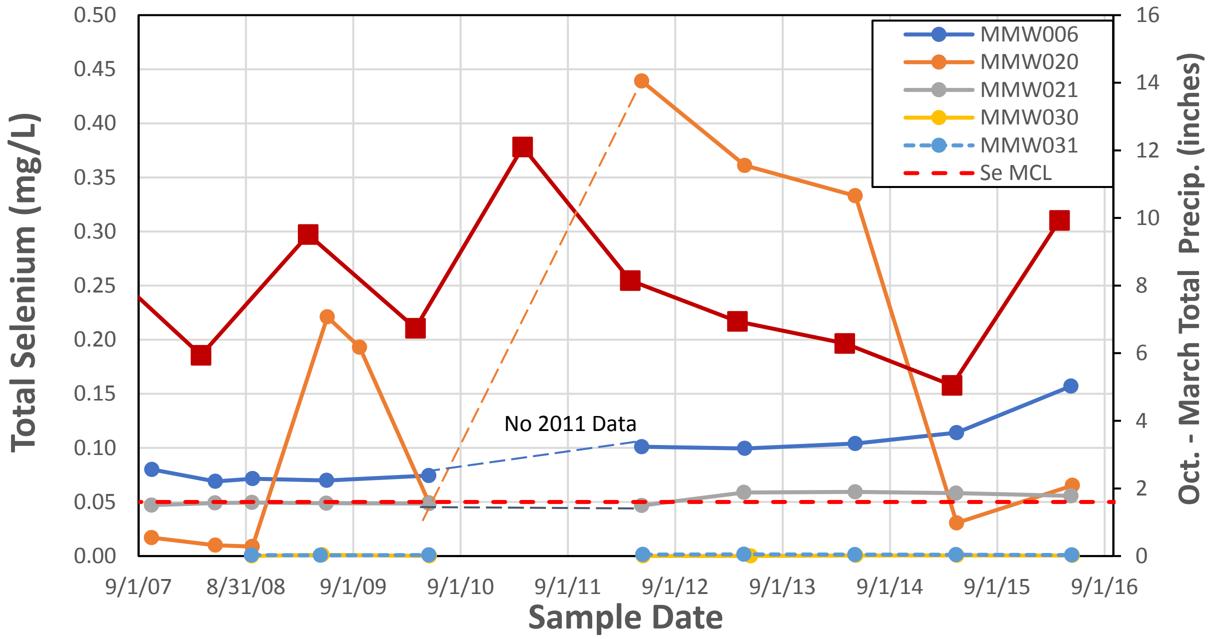

Figure 3-3. Plot of Total Selenium Concentrations Over Time in Wells Formation Monitoring Locations

The reader is directed to the *Ballard RI Report* for a detailed presentation and discussion of the Wells Formation hydrogeologic data around the West Ballard Pit (MMP035) including evaluation of potentiometric, temperature, and concentration data. Key conclusions associated with these data relevant to this MNA discussion and the relationship between the monitored zones around the West Ballard Pit are as follows:

- No other Site modifications have occurred in the last 40 or more years that would readily explain a now increasing trend in MMW006 concentrations. The most logical explanation is a response to increased infiltration during a wet year, similar to what is observed in MMW020, however, in a more muted fashion because of the travel path through lower permeability bedding, as would be any related future downward trend in concentrations.
- A muted response to changes in potentiometric and chemical conditions would be expected at locations, like MMW006 and MMW021, because transport across lithologic bedding is expected to be much more limited, even though, the stratigraphic (perpendicular to the bedding planes) distance may be relatively close (e.g., 100-150 feet) as depicted on cross-section H-H' shown on **Drawing 2-4**.
- It is reasonable, and even probable, that both MMW006 and MMW021, respond to increases in concentrations observed at MMW020 in a more delayed manner as flow has to be transported across lower permeability bedding within the formation. The cross-section presented on **Drawing 2-4** helps to illustrate this concept.
- Based on the data, the source of contamination detected at MMW006 is the seeps and springs that discharge from the waste rock above the eastern pit highwall. The proposed

preferred alternative would significantly reduce and control the sources of contamination to the Wells Formation, including undetected infiltration through the waste rock, by rerouting the spring water and favorably regrading/contouring and covering the adjacent waste rock.

- Because of MMW030's location in a recharge area for the Wells Formation, it is clear that the contamination at the West Ballard Pit is confined in that direction. The same is true for the MMW031. The data from these wells are consistent with the CSM for the Site of an overall regional flow in the Wells Formation toward the Henry Springs to the north-northwest of the Site approximately 5.5 miles to the north. This is the closest known discharge point for impacted Wells Formation water from the Ballard Site.

Chemical Properties Relevant to MNA. Chemically, the selenium attenuation capacity of the Wells Formation has not been evaluated at the Ballard Site. However, it has been evaluated in several new phosphate mine permitting studies with similar stratigraphic packages including the Wells Formation. These data, presented in **Table 3-1** below, were summarized in the Final Environmental Impact Statement (FEIS) for the Smoky Canyon Mine, Panel F & G (BLM/USFS, 2007), which also discusses selenium attenuation processes in detail. Selenium geochemistry and attenuation process also are discussed in detail in the *P4 Sites RI/FS Work Plan*.

TABLE 3-1
PHOSPHATE AREA WELLS FORMATION ATTENUATION DATA

ATTENUATION EVIDENCE	EFFECTIVENESS (%)
Literature	11 - 46
Smoky Canyon Mine – Pole Canyon to Hoopes Spring*	50
Smoky Canyon Mine – Panel A to Culinary Well*	30 - 60
Smoky Canyon Mine – Batch Tests (1:4 to 1:10 rock:water ratio)	21 - 26
Dry Valley Mine – Batch Tests (1:4 rock:water ratio)	64

* Empirical data may also include the effects of dispersion and diffusion.
Data from BLM/USFS, 2007.

The data summarized in **Table 3-1** show that the Wells Formation rock generally has moderate to weak attenuation capacity. Most of the attenuation studies associated with the Wells Formation focused on the capacity for selenium to adsorb to carbonates in the unit. Biochemical attenuation also could be a factor. However, it has been generally thought that the organic carbon content needed for biological processes is not high enough in the Wells Formation to make this a primary attenuation mechanism.

The data from analyses and measurements in groundwater samples collected at MMW020 support the hypothesis of Wells Formation attenuation at that location. There are lower concentrations of selenium at MMW020 associated with lower DO and ORP. **Figure 3-4** shows the DO correlation. The correlation with ORP (not shown on **Figure 3-4**) is similar, but more erratic, possibly because of the difficulty in getting accurate measurements for this parameter in the field.

The low DO content may indicate biological activity that is effective in attenuating selenium when not overwhelmed by infiltration of large amounts of fresh oxygenated water from the seeps and spring. Therefore, when the seep/spring inflow is cut off as planned in the remedial action (i.e., through rerouting of this source to an engineered wetland), these data suggest that selenium will be attenuated. However, additional data needs to be collected at the MMW020 location to understand the mechanism of selenium attenuation. Further evidence of attenuation at MMW020 is discussed below.

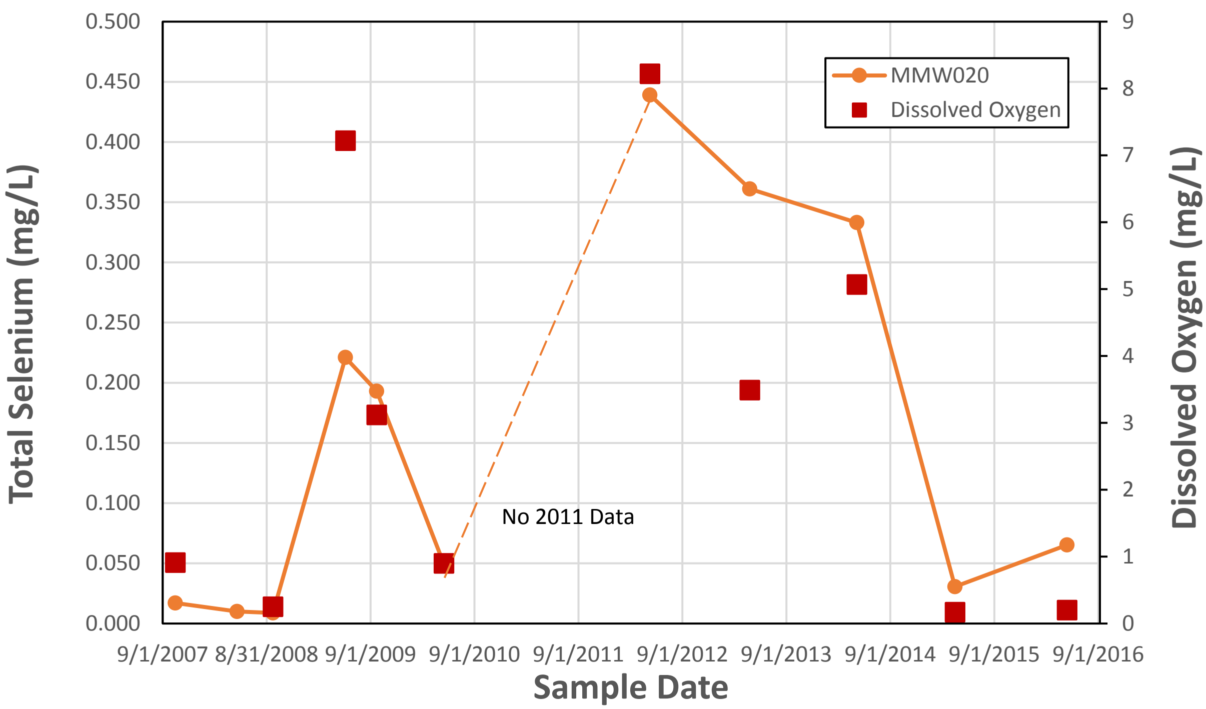

Figure 3-4. Plot of Total Selenium and Dissolved Oxygen for Monitoring Well MMW020

Evaluation of Se:SO4 ratios. Similar to the alluvial aquifer, most of the impacted Wells Formation monitoring wells do not currently show evidence of attenuation, with an exception in MMW020 (**Figure 3-5**). Two Wells Formation monitoring wells, MMW030 and MMW031, and one Dinwoody Formation well, MMW033, are shown on **Figure 3-5** that exhibit background groundwater quality as shown on the graph.

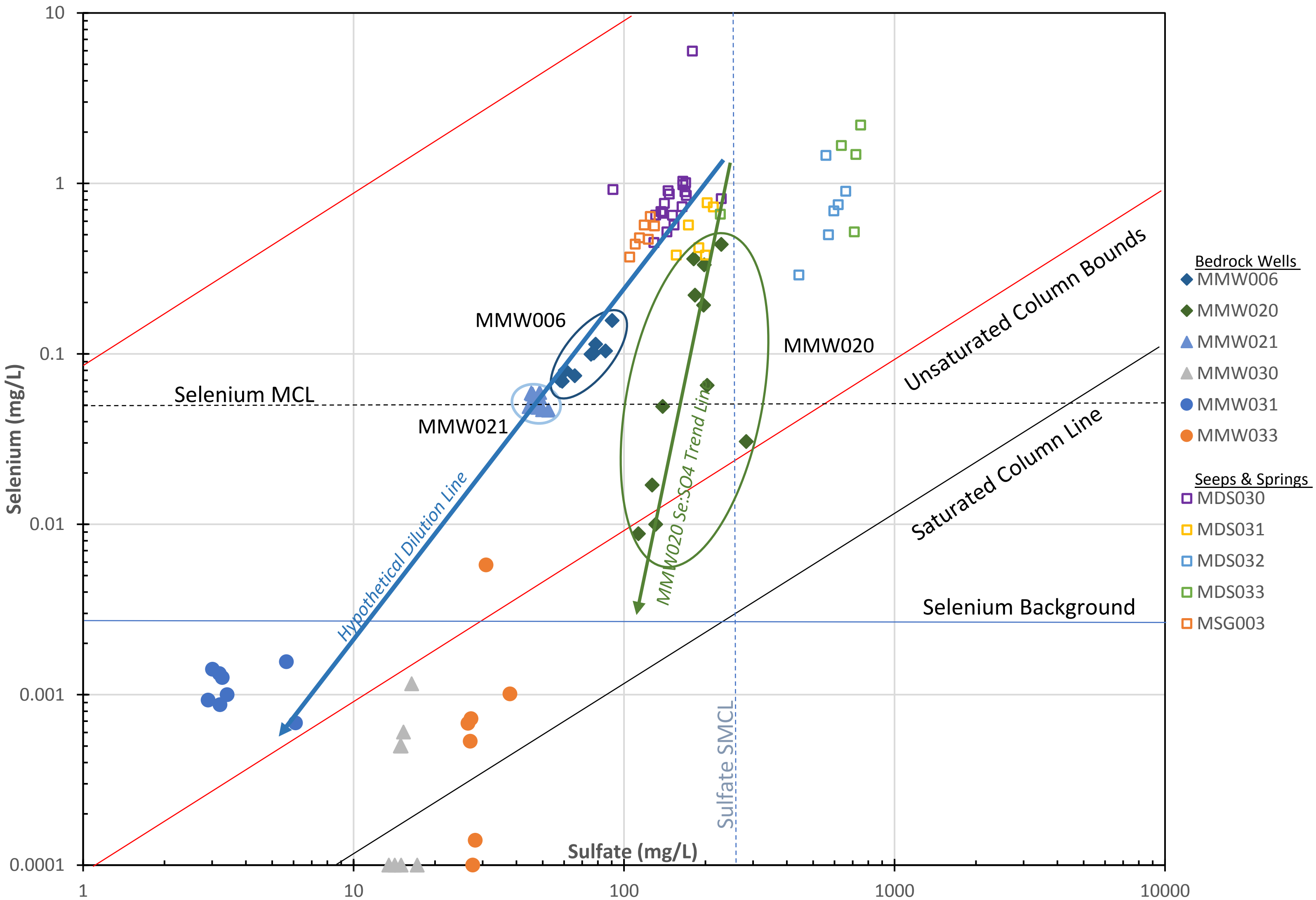

Figure 3-5. Plot of Total Selenium and Sulfate for Bedrock Monitoring Wells and Seeps/Spring (Note data collection from 2007 – 2016 for wells and 2004 – 2016 for seeps/spring)

Containing background concentrations, these wells are not relevant to the attenuation discussion, but are shown as a comparison point. The water quality and $Se:SO_4$ ratios in MMW021 are generally invariant, and MMW006 is intermediate, possibly a blend of MMW021 and the higher concentrations detected at MMW020. The trends shown on **Figure 3-3** also support this conclusion. It appears that concentrations, and therefore groundwater movement at MMW021 and possibly MMW006, are relatively static, and the attenuation capacity of the aquifer has locally been exhausted.

The trend in $Se:SO_4$ ratios at MMW020 is distinctly different than the other Site monitoring wells installed in the Wells Formation. As noted in the *Ballard RI Report,* and shown on **Figure 3-3**, the concentrations observed in MMW020 respond to changes in response to the surface infiltration rate, increasing with heavy winter precipitation and associated increased seep discharge to the mine pit. It was assumed that lower concentrations were due to mixing and dilution with unimpacted groundwater (i.e., a lower percentage of impacted groundwater compared to unimpacted groundwater). However, **Figure 3-5** supports that attenuation is an important component of contaminant reduction at this location, having its greatest effect when not overwhelmed by a higher rate of impacted water inflow.

If dilution were the only mechanism for reducing the sulfate and selenium concentrations, then the percent reduction in concentrations for both analytes would be the same (e.g., if deionized water was the diluent). However, the diluent at the Site is background groundwater that contains concentrations of both selenium and sulfate. In this case, any mixtures that result from dilution should lie on a mixing line between the source quality (e.g., MDS030) and the background quality (i.e., monitoring wells MMW030 and MMW031 for the Wells Formation on the Site). This hypothetical mixing line is shown on **Figure 3-5**. A large variation from this expected trend supports preferential removal of one of the components.

At MMW020, the sulfate concentrations have varied from 113 to 229 mg/L (approximately double), while correlative selenium concentrations have varied from 0.00881 to 0.439 mg/L (a 50X change), as shown on **Figure 3-5**. There is a slight trend toward sulfate background suggesting that dilution or possibly sulfate attenuation is occurring, but it appears selenium is being reduced with respect to sulfate.

The trend in the Se:SO4 ratios in groundwater from MMW020, along with the DO concentrations, (**Figure 3-4**) indicate that selenium attenuation is active at that location, and therefore, can occur elsewhere in the Wells Formation. It is uncertain as to why the same effects are not observed in MMW006 and MMW021. It is possible that the infiltrating seep/spring water contains dissolved organic content after infiltrating through waste rock and debris in the pit bottom, and this enhances biological activity. Further studies will be needed to understand the attenuation processes observed at MMW020, and how it relates to attenuation in the overall aquifer. However, at a minimum, it appears that once the source is controlled, attenuation processes will begin to reduce selenium concentrations in the aquifer initially closest to the source.

At this time, the assumption is that biological reduction is responsible for the observed attenuation at MMW020. However, if the following is assumed;

- Biological reduction is occurring at the location;
- The source of selenium is the same as the carbon; and
- The supply of both selenium and carbon is significantly reduced as the result of the remedy;

then it is probable that enough carbon will be present to reduce the selenium concentration to less than the MCL at the MMW020 location as the result of the remedial action.

This hypothesis is based on the observation that such a reduction already occurs during periods of low recharge. If there is excess carbon, then the greater the excess, the greater the area of attenuation may be as the carbon disperses into the Wells Formation. Attenuation at the MMW020 location appears to be effective and rapid, and removal of the source of oxygenated, selenium-enriched infiltration would allow any in-situ biochemical attenuation processes to quickly dominate. Attenuation in the more distal portions of the Wells Formation (e.g., MMW006) may be more dependent upon the primarily sorption mechanisms quantified in **Table 3-1**.

Post-RA Conditions for MNA. Without a high organic content in the Wells Formation unit (BLM/USFS, 2007), it might be difficult for anoxic conditions to develop that are favorable to biologically-mediated selenium attenuation throughout the aquifer. However, once the source of oxygenated selenium-impacted water is cut off with source controls (i.e., partial pit backfill, regrading/contouring, and ET cover system), then more reduced or suboxic conditions can more easily develop and would be maintained in the impacted units. Such conditions would enhance attenuation in the Wells Formation aquifer. In absence of such conditions, the sorption processes quantified in **Table 3-1** would dominate at a slower rate. Studies that support attenuation in saturated suboxic conditions are referenced above for alluvial groundwater in Section 3.2.1.

3.3 USE OF MNA AT BALLARD SITE

MNA is a viable groundwater remedy component and the preferred alternative for polishing alluvial and Wells Formation groundwater at the Site for the following reasons:

- It substantively meets the regulatory requirements for the use of MNA, most notably the use of source controls as a key component of the overall remedy. Source control is the primary component of the proposed remedy, and source control will significantly reduce the mass loading of COCs to Site groundwater. As discussed in Section 2.3, the proposed ET cover would result in an estimated 13-fold reduction in infiltration rates (MWH, 2017b). The ET cover also will reduce air flow into the waste rock, helping to develop suboxic conditions and encouraging selenium attenuation in the dumps, and further reducing COC loading from the source areas. In addition, installation of PRBs above seep/spring locations will attain groundwater PCLs when installed and will reduce COC loading in groundwater in the interim until the ET cover systems (i.e., source controls) are completed and have been effective at reducing the groundwater flux.
- The majority of the alluvial and Wells Formation groundwater impacts are located on P4 property and where they are not, P4 is pursuing land purchase or land exchanges in order to control the beneficial use of these areas. In addition, no domestic wells are known to be installed in the alluvial or Wells Formation aquifers in the vicinity of the Ballard Site. As a result, there are no current receptors, and in the future, there would be no anticipated users/receptors of the mine-affected groundwater. As a result, there is not a significant risk driver for a potentially faster, but costlier remedial alternative for treatment of Site groundwater.
- ICs as discussed in Section 2.3 would be implemented on all the lands controlled by P4 to restrict withdrawal and use of shallow and deeper groundwater during the RA and in the long term until LTM indicates the cleanup levels have been achieved.
- The plume geometries in the alluvial aquifer are known and are depicted on **Drawings 2-6** and **2-7**. The Wells Formation geologic/hydrogeologic setting is complex, but the configuration and perimeter monitoring well data support that groundwater flow out of the Site is limited because of compartmentalization. In both cases, significant downgradient area exists without potential receptors and is available for plume attenuation, dilution, and dispersion, along with a source of clean upwelling water from the Dinwoody Formation on the east side of the Site. The lone exception is the plume flowing toward the Blackfoot River, where the riparian/wetlands zone near the river may be a significant attenuation zone.
- Selenium data from the alluvial aquifer support that the plumes are not substantially growing, but rather have concentrations that are relatively static. However, the plume edges were largely defined using one-time grab sampling with direct-push borings, and these groundwater samples were only analyzed for selenium, which limits the information available for plume and MNA evaluations.
- Selenium:sulfate and DO/ORP measurements from both the alluvial and Wells Formation aquifers suggest that attenuation process are present, but are limited; this in part, may be due to monitoring well placement.

- Data from the Wells Formation indicates some attenuation potential ranging from 11 to 64 percent effectiveness (BLM/USFS, 2007; BLM, 2011). Data from MMW020 indicates that attenuation is occurring in the Wells Formation at that location. This attenuation may be biologically mediated, and it is uncertain why it is not being observed in other wells near the West Ballard Pit.
- The uncertainties would be addressed for both the Wells Formation and alluvium aquifers during pre-design studies (see Section 4.0), which would evaluate attenuation and reduction potential (e.g., organic carbon availability). In both cases, lower attenuation capacity and longer clean up time may be offset by long flow paths and groundwater inaccessibility (e.g., Wells Formation depth, faulting/structural isolation, and heterogeneity).
- The use of pit back fill and engineered ET covers will reduce the oxygenation of the waste rock, allowing potential reduction of the pore water by organic matter within the Meade Peak Member. The movement of reduced (i.e., anoxic) water into the aquifers would assist MNA as suggested by observations at MMW020 in the Wells Formation aquifer and MW-16A in the alluvial aquifer.
- The seeps and springs that currently are the primary sources of alluvial groundwater impacts (at the margins of the waste rock dumps) and Wells Formation groundwater impacts near the West Ballard Pit system will be treated through planned PRBs/engineered wetlands. For the Wells Formation, the seep/spring water will be routed away from the mine pit and treated at the margin of the remediated mine dumps. This means that loading to the Wells Formation will be substantially eliminated.

These factors are considerations as to the selection of MNA in the alluvial and Wells Formation aquifers. Any active remediation would be difficult, complex and costly, and possibly create more issues than it solves (e.g., the need to discharge groundwater).

Data gaps for further evaluation of MNA at the Site include:

- New monitoring wells located within plume cores, along leading edge of plumes, and near the Blackfoot River fluvial/wetland area.
- Specific aquifer solid material properties that relate to MNA processes.
- Groundwater sampling and analyses to evaluate additional groundwater chemistry properties in support of MNA, especially in association with MMW020, MW-16A, and MBW009 to understand the active attenuation mechanisms observed at those locations.

Additional data collection and long-term monitoring will be necessary to address data gaps involved with MNA. P4 proposes that additional monitoring and evaluations be performed through collection of groundwater and aquifer solids data from existing and new monitoring points. The pre-design Ballard Site MNA evaluation will follow the 2015 USEPA guidance as further discussed in Section 4.0 to address the data gaps that have been identified.

4 PLAN FOR IMPLEMENTATION

The section discusses the steps needed to advance the evaluation of MNA as part of the Site-wide remedy along with the monitoring program that will be needed to implement MNA. Both components will be greatly expanded during the Site RD process. MNA evaluation will follow the USEPA tiered-approach to characterization (refer to Section 2.4) in order to develop multiple lines of evidence to support the viability of MNA at the Site.

4.1 PRE-DESIGN STUDIES

Collection of supplemental MNA data will be necessary to further support the existing MNA evidence and evaluations presented in this *MNA Memo* and to address MNA data gaps noted in Section 3.0. The USEPA 1999 and 2015 guidance will be followed to focus and prioritize collection of additional data that will be used to further support/refine the existing Site MNA information. Preparation of a Pre-Design MNA Sampling and Analysis Plan (SAP) will be necessary to confirm plume stability and to evaluate the mechanism(s) and rate of attenuation processes (combined Phase I and Phase II of USEPA tiered-approach) found at the Site.

Elements of the future Phase I and Phase II could include the following:

- Phase I – Plume Stability Evaluations (refer to Section 3.0)
    - ✓ Groundwater flow direction (calculation of hydraulic gradients); aquifer hydrostratigraphy
    - ✓ Contaminant concentrations/distribution in groundwater aquifers
    - ✓ General groundwater chemistry data
- Phase II – Mechanism and Rate of the attenuation process
    - ✓ Detailed characterization of system hydrology (spatial and temporal heterogeneity; flow model development)
    - ✓ Detailed characterization of groundwater chemistry
    - ✓ Subsurface mineralogy and microbiology
    - ✓ Contaminant speciation (groundwater and aquifer solids)
    - ✓ Evaluate reaction mechanism (site data, laboratory testing, develop chemical reaction model)

For the Phase I elements, the existing data presented in Section 3.0 is enough to assist with the MNA evaluation. However, with the addition of new Site monitoring wells in strategic locations, additional confirmation can be made regarding the groundwater flow direction(s), contaminant concentration and distribution, and general groundwater chemistry. Phase II elements will require new studies and a combination of existing data with new data to augment the current MNA conceptual model and how it will evolve once the Site remedy is in place.

A Phase III evaluation within the USEPA tiered-approach framework (i.e., to determine the capacity of the aquifer to attenuate the estimated mass of contaminants and resist re-mobilization) will be reviewed following the pre-design studies listed below to determine if it is necessary with the data collected at that point in the process.

4.1.1 Aquifer Material Characterization

Data will be collected from the alluvial aquifer and may be collected from the Wells Formation aquifer to define aquifer solids composition and chemical speciation of the aquifer solids for evaluation of the attenuation mechanisms consistent with USEPA 2015 guidance. In addition to the existing monitoring wells, new wells will be installed in strategic locations in unaffected (background) areas, along plume edges, within impacted areas, and in fluvial area(s) near the Blackfoot River.

Testing of the aquifer solids material could include total metals, mineralogy, total organic carbon, cation exchange capacity, and batch attenuation tests. Based on the total selenium concentrations in the core samples, sequential extraction procedures (SEP) for selenium may be performed on specific samples, especially in plume core areas near the sources where attenuation is likely to have occurred (but may be exhausted), and COCs are likely sequestered in the aquifer matrix. Testing will consider existing, as well as projected future conditions (i.e., following source control/waste rock capping). The details of this aquifer solids testing program including the location of new wells and laboratory tests will be specified in the Pre-Design MNA SAP.

4.1.2 Groundwater Sampling

As discussed above, along with the existing monitoring wells, new monitoring wells may be installed in strategic locations in the unaffected areas, along the leading edges of plumes, and near the Blackfoot River. These new pre-design and compliance monitoring wells (along with existing monitoring locations) would be sampled to evaluate attenuation indicator parameters consistent with USEPA guidance (2015). Monitoring parameter likely would include water levels, field parameters (pH, conductivity, DO, ferrous iron, ORP, turbidity, and temperature), general groundwater chemistry (major anions and cations), total metals, total organic carbon, and selenium speciation data in the Wells Formation. The details of this groundwater sampling program will be specified in the Pre-Design MNA SAP.

4.2 LONG-TERM MONITORING – PRELIMINARY SCOPE

Long-term performance monitoring (LTM) or performance monitoring (Phase IV from the USEPA guidance [2015]) ultimately will provide the necessary data to evaluate whether the proposed overall Site remedy discussed in Section 2.3 can achieve RAOs in a reasonable timeframe. Implementation of LTM will require preparation of a SAP, routine groundwater monitoring throughout the various plumes, and periodic data evaluations to track the progress of natural attenuation and to support CERCLA 5-year reviews. This is similar to the LTM program that is currently conducted at the Site, but the frequency of sampling and the analyses conducted will be for the ongoing MNA evaluation, as well as the contaminant monitoring, which is the object of the current LTM program.

A conceptual LTM monitoring well network is shown on **Drawing 2-5**. The network includes existing sampling locations and proposed strategic new locations (e.g., POC locations), established near P4's property line to provide a greater density and more uniform distribution of monitoring locations to monitor compliance with RAOs. Groundwater samples will be analyzed for a suite of parameters similar to the parameters proposed for the pre-design studies (e.g., field parameters, cations, anions, and metals). Concentrations over time at individual wells within the plume and statistical analysis of data trends will be evaluated and reported following LTM data collection. Program details would be refined during RD and during the preparation of the LTM SAP.

ICs will be implemented on all P4-owned lands, and as necessary, on private land adjacent to the Site through legally binding agreements to restrict withdrawal and use of groundwater until ARARs are achieved.

Under CERCLA's review process, LTM data would be summarized annually, then evaluated at 5-year intervals to determine if remedy components are achieving the RAOs (i.e., during the CERCLA 5-year reviews). If proposed remedies for groundwater (source control, PRBs/wetlands at seeps and springs and MNA) do not achieve RAOs at approved POC locations within a reasonable time frame, as established by USEPA in consultation with P4, the remedy would be evaluated and if necessary, adapted to include other viable remedial technologies for treating groundwater. The LTM data and possible alternative changes would be evaluated, discussed among stakeholders, and as necessary, refined then implemented as part of the CERCLA 5-year review process.

4.3 REPORTING

Data collected during the pre-design studies would be summarized in a field investigation report attached to the RD or RA Work Plans, depending on the submittal schedule for these documents. LTM data would be validated and summarized at the end of each year in Data Summary Reports (DSRs) and would include location maps and tabulated data. The CERCLA 5-year reviews will include more detailed review of the LTM data (e.g., attenuation mechanisms, risk for contaminant mobilization, monitoring network and parameter lists) and evaluate the continued protectiveness of the Site-wide remedy until RAOs are achieved.

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USEPA, 2007a. *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 1 – Technical Basis for Assessment*. EPA/600/R-07/139. October 2007.

USEPA, 2007b. *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 2 – Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium*. EPA/600/R-07/140. October 2007.

USEPA, 2009. *Administrative Settlement Agreement and Order on Consent/Consent Order for Performance of Remedial Investigation and Feasibility Study at the Enoch, Henry, and Ballard Mine Sites* i*n Southeastern Idaho.* United States Environmental Protection Agency, U.S. EPA Region 10, Idaho Department of Environmental Quality, United States Department of Agriculture, Forest Service Region 4, United States Department of the Interior, Bureau of Land Management, Shoshone-Bannock Tribes, in the Matter of Enoch Valley Mine, Henry Mine, Ballard Mine, P4 Production, L.L.C., Respondent. Effective Date of November 30.

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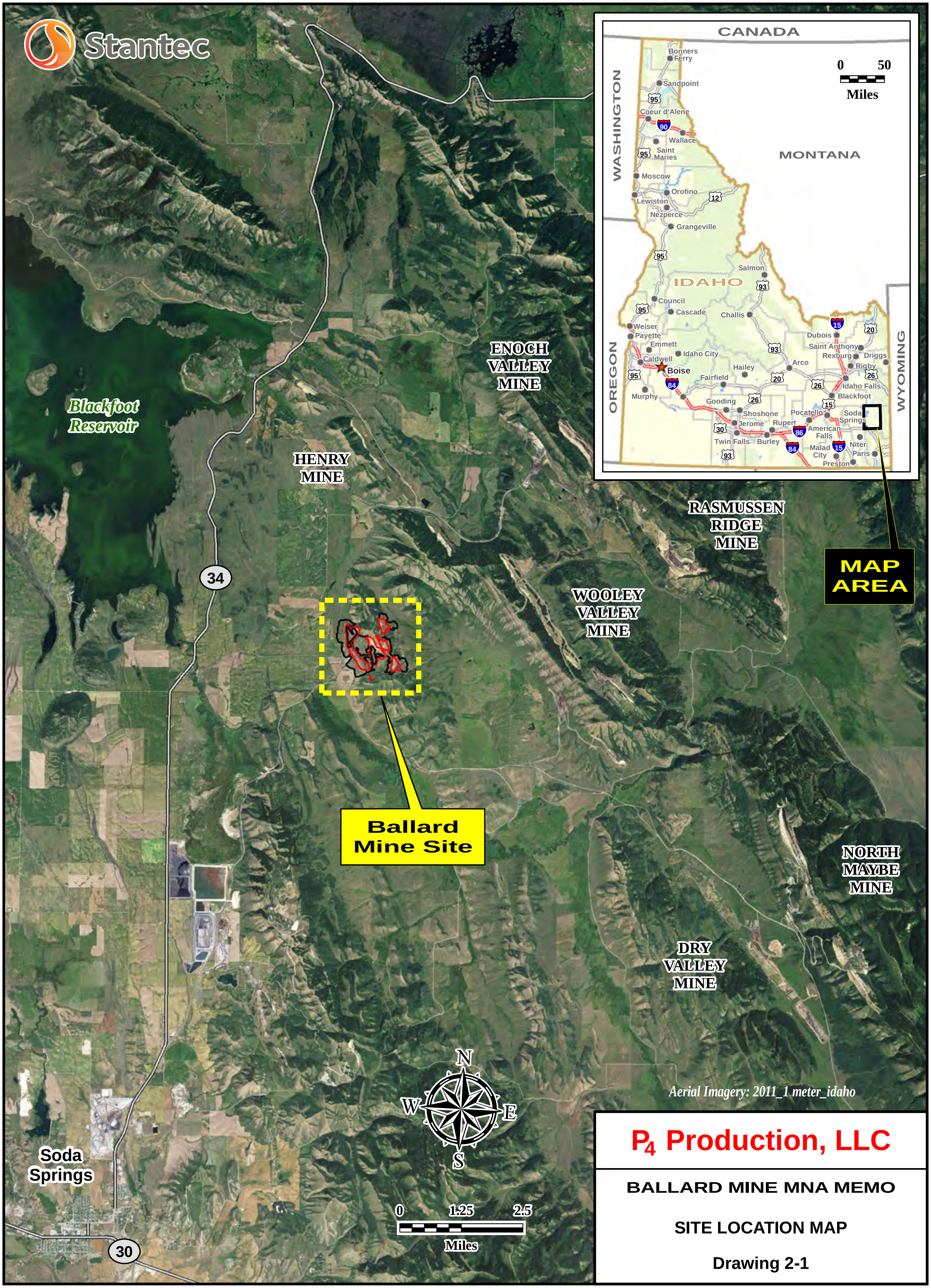
DRAWINGS



P$_4$ Production, LLC

BALLARD MINE MNA MEMO

SITE LOCATION MAP

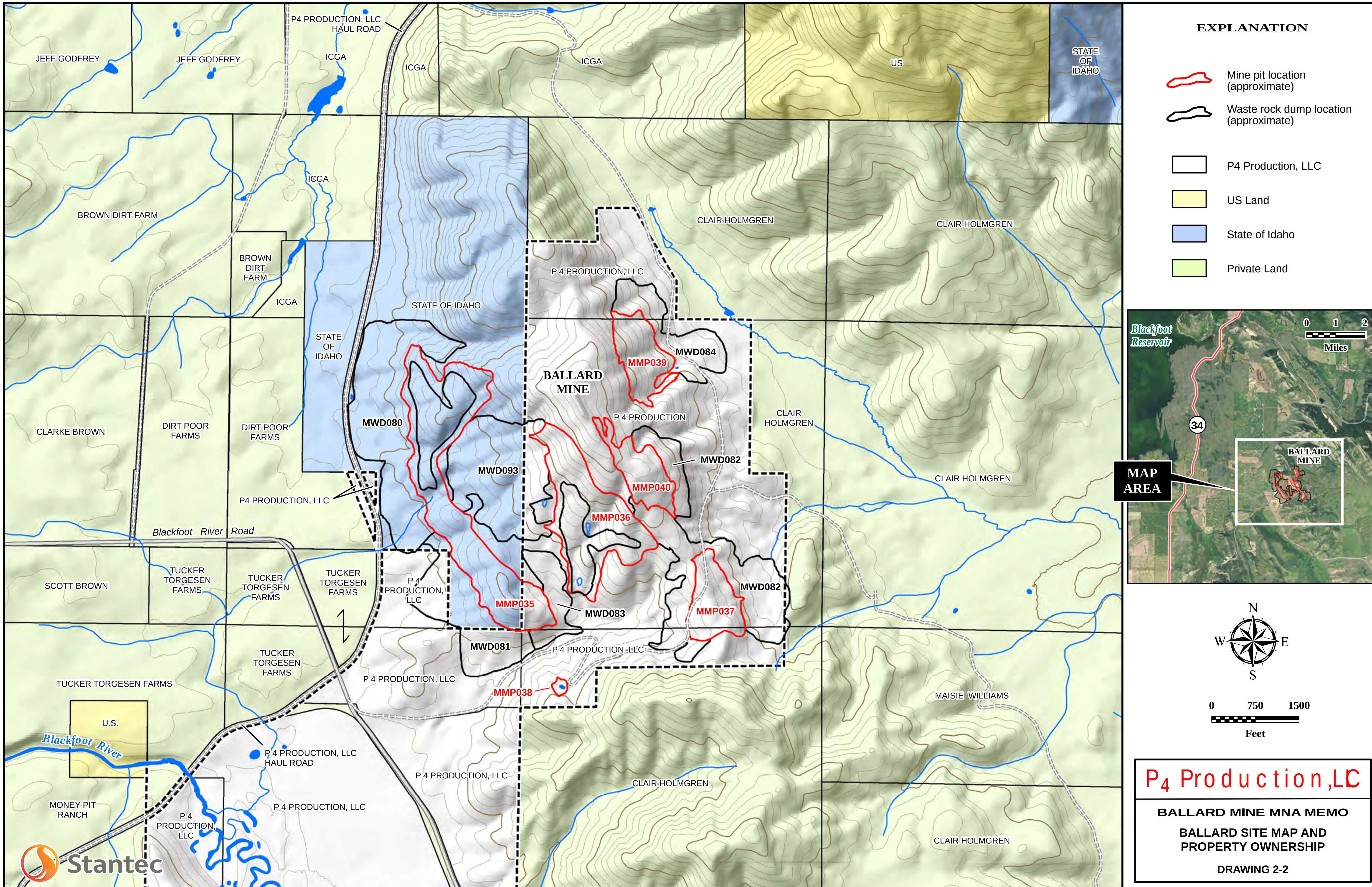
Drawing 2-1

DRAWN BY D. Severson

14 Sep 2017

C:\Data\MWH\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Dwg 2-1_Ballard Mine_Site Location Map_14Sep2017.mxd

DRAWN BY D. Severson
14 Sep 2017
C:\Data\MWH\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Dwg 2-2_Ballard Mine Site_Property Ownership_14Sep2017_withindex.mxd



P4 Production, LLC

BALLARD MINE MNA MEMO

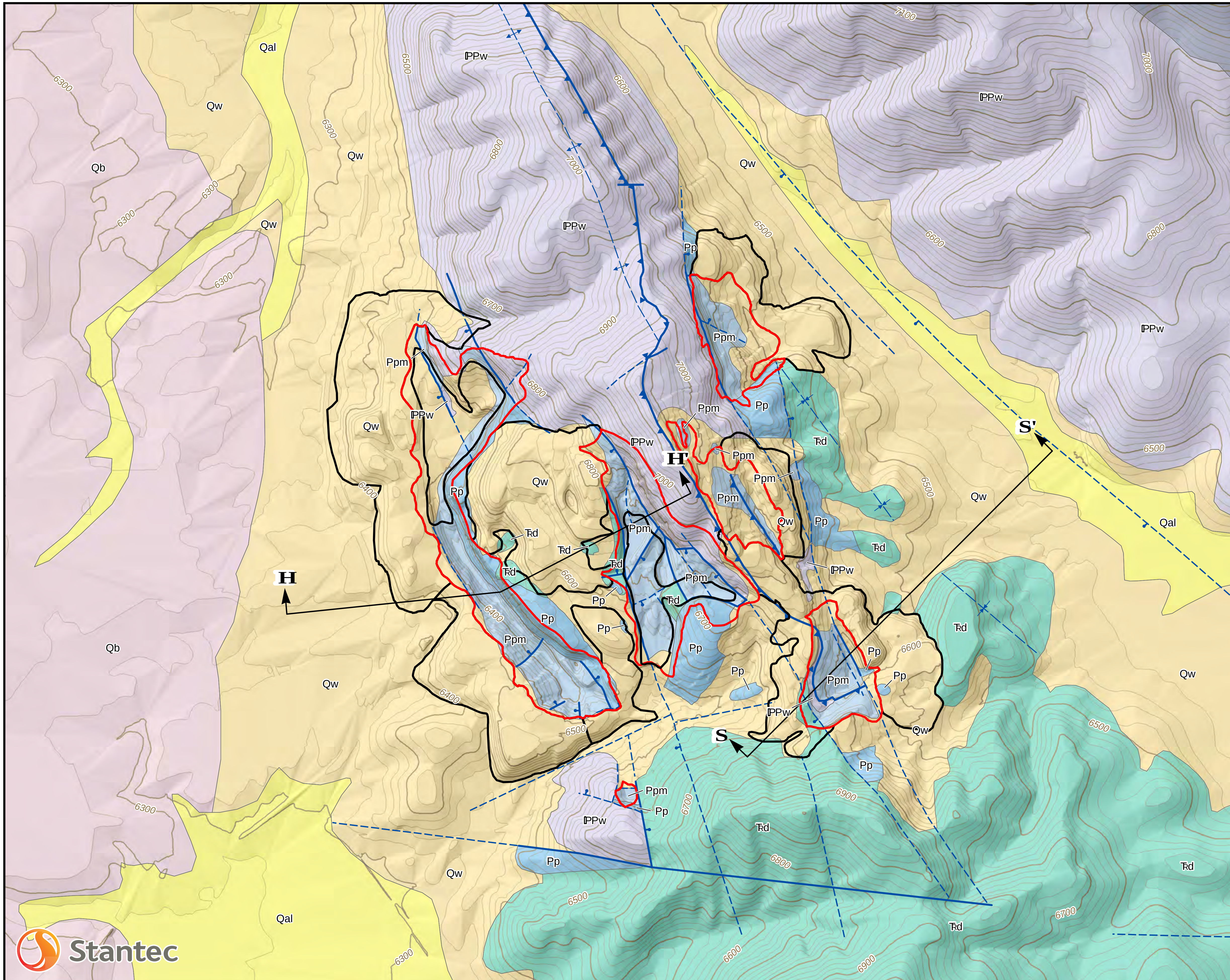
BALLARD SITE MAP AND PROPERTY OWNERSHIP

DRAWING 2-2

DRAWN BY D. Severson

14 Sep 2017

C:\Data\MWH\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Dwg 2-3_Ballard_Generalized Geologic Map_14Sep2017.mxd



EXPLANATION

Qb	Basalt
Qal	Alluvium
Qw	Colluvium and older alluvium, may include areas covered in mine waste rock
TRd	Dinwoody Formation - Woodside Shale
Pp / Ppm	Phosphoria Formation Meade Peak Member
PPw	Wells Formation
Mb	Brazer Limestone

Fault

Approximate or inferred fault

Normal fault (ball on downthrown block)

Thrust fault

Axis anticline

Axis syncline

Approximate mine pit location

Approximate waste rock pile location

S S' Line of cross section (see Drawing 2-4)

N W E S

0 600 1200

Feet

CONTOUR INTERVAL 20 FEET

GEOLOGIC DATA SOURCES: Hovland, 1981; Mansfield, 1927

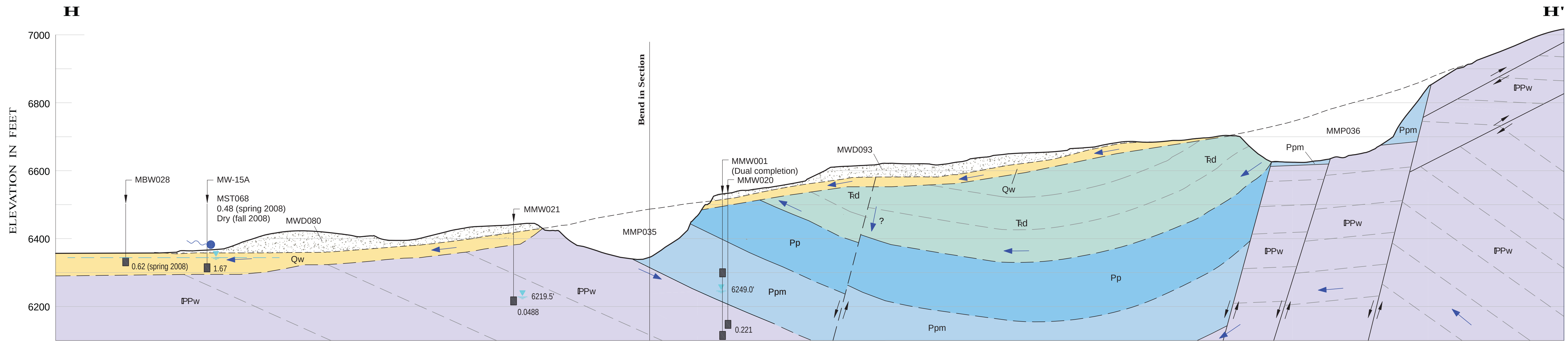
P_4 Production, LLC

BALLARD MINE MNA MEMO

GENERALIZED GEOLOGIC MAP

Drawing 2-3

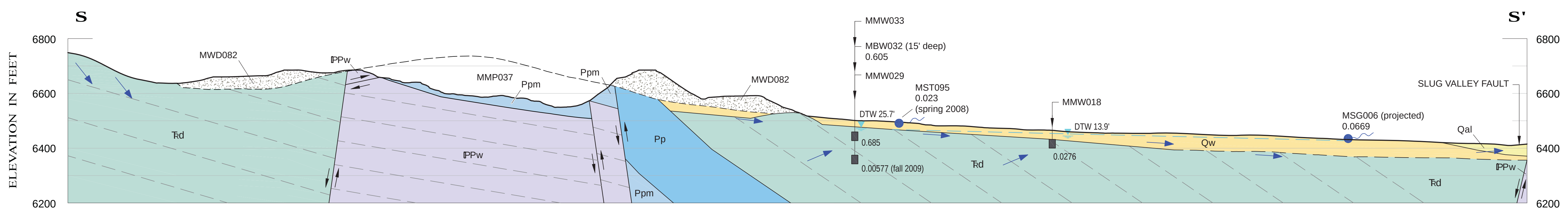
DRAWN BY D. Severson
12 Oct 2017
C:\Data\MWH\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Dwg 2-4_Cross Section_H-H_S-S_original_12Oct2017.ai



SECTION H-H'

0 150 300

Horizontal and Vertical Scale in Feet
NO VERTICAL EXAGGERATION



SECTION S-S'

0 100 200

Horizontal and Vertical Scale in Feet
NO VERTICAL EXAGGERATION

Waste rock
Pre-mine surface
Geologic contact
(dashed where approximate or inferred)
Fault, showing direction of displacement
(dashed where inferred)
Schematic groundwater flow vector
6236' Measured groundwater elevation
(feet above mean sea level)

Potentiometric surface
DTW 25.7' Typical depth to water in feet
0.685 Measured total selenium concentration in mg/L
(fall 2008 sample, unless otherwise noted)
Monitoring well location showing approximate
screen location
Spring or dump seep

Qb Basalt
Qal Alluvium
Qw Colluvium and older alluvium,
may include areas covered in
mine waste rock

Ŧd Dinwoody Formation - Woodside Shale
Pp Phosphoria Formation
Ppm Meade Peak Member
IPPw Wells Formation
Mb Brazer Limestone

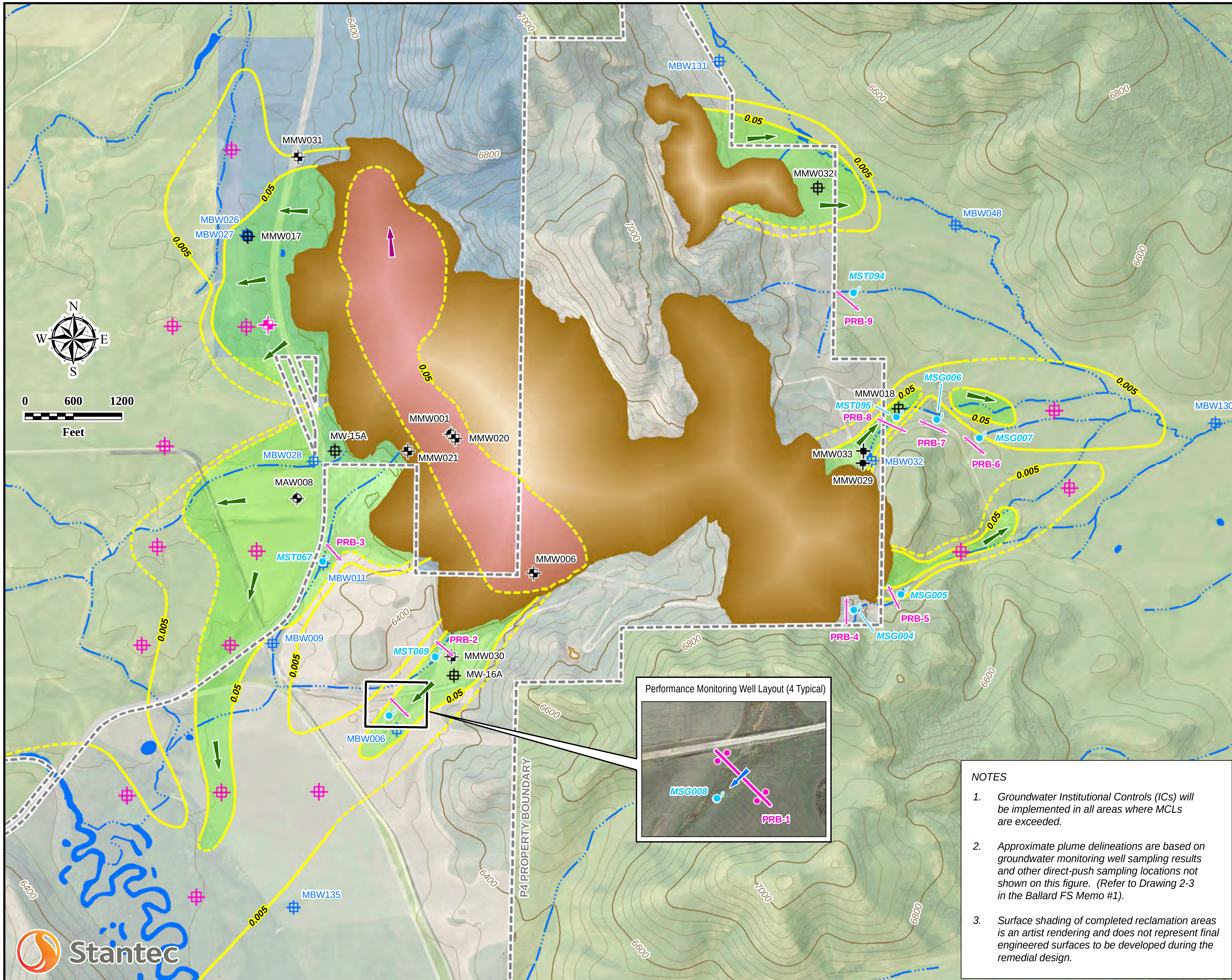
Stantec

P4 Production, LLC

BALLARD MINE MNA MEMO

DRAWING 2-4

CROSS SECTIONS H-H' AND S-S'



EXPLANATION

PROPOSED NATURAL ATTENUATION MONITORING NETWORK

- Existing direct push alluvial aquifer well
- Existing agricultural, domestic or production well
- Existing local aquifer monitoring well (generally alluvial system)
- Existing intermediate aquifer monitoring well (generally Dinwoody Formation)
- Existing regional aquifer monitoring well (Wells Formation)
- Proposed new alluvial monitoring well
- Proposed new Wells Formation monitoring well
- Estimated completed reclamation areas in upland soil/waste rock.
- Approximate alluvial groundwater plume >selenium MCL. (indicates approximate direction of groundwater flow.)
- Approximate Wells Formation groundwater plume >selenium MCL. (indicates approximate direction of groundwater flow.)
- Total selenium isoconcentration contour (mg/L)
- Inferred total selenium concentration contour (mg/L)
- mg/L Milligrams per liter
- MCL Maximum Concentration Level
- Mine-affected seep/spring
- Performance monitoring well (approximately 25 feet from PRB)
- Proposed Permeable Reactive Barrier (PRB)

NOTES

1. *Groundwater Institutional Controls (ICs) will be implemented in all areas where MCLs are exceeded.*
2. *Approximate plume delineations are based on groundwater monitoring well sampling results and other direct-push sampling locations not shown on this figure. (Refer to Drawing 2-3 in the Ballard FS Memo #1).*
3. *Surface shading of completed reclamation areas is an artist rendering and does not represent final engineered surfaces to be developed during the remedial design.*

P_4 Production, LLC

BALLARD MINE MNA MEMO

GROUNDWATER ALTERNATIVES PRBs, MNA, AND ICs

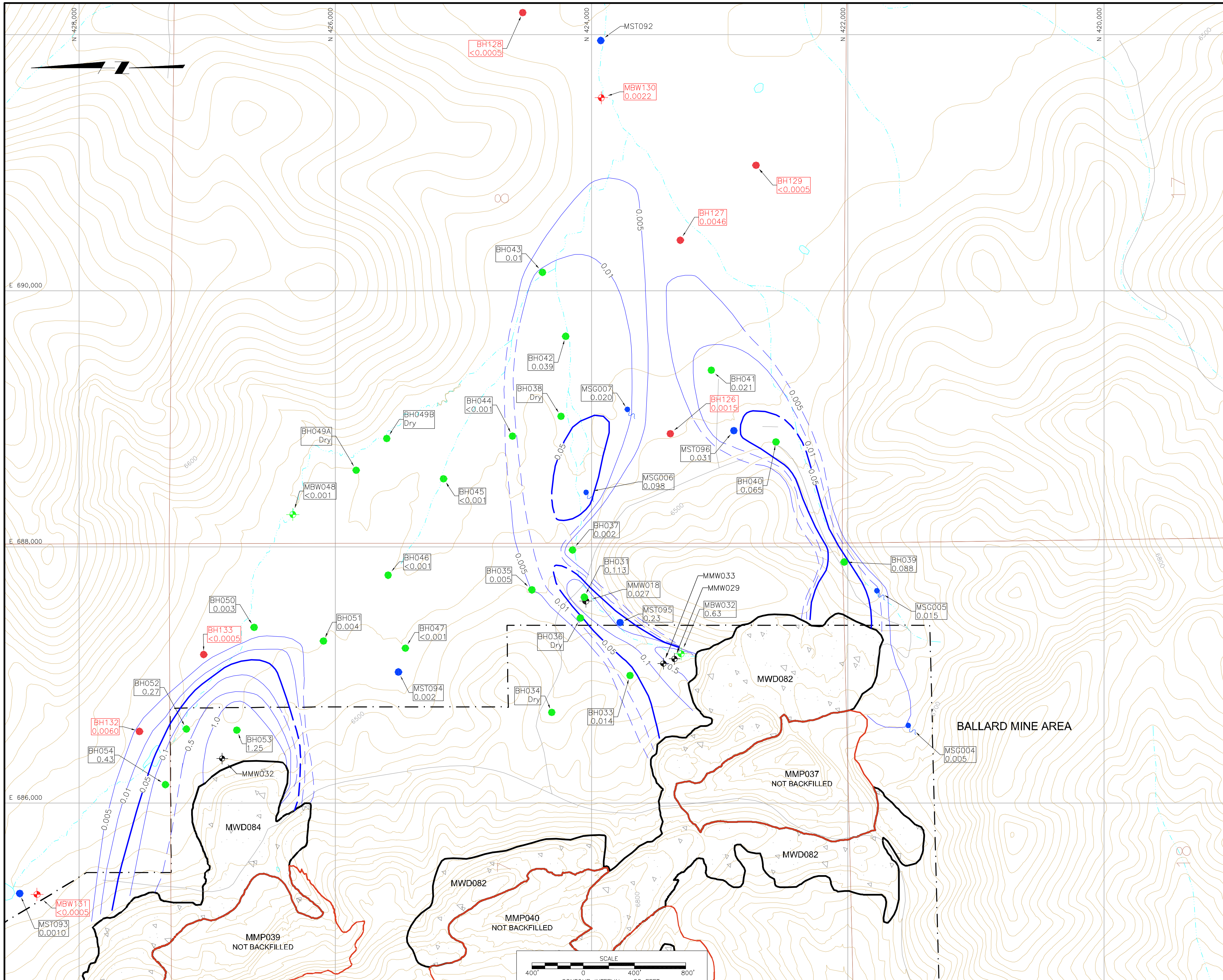
DRAWING 2-5

Stantec

DRAWN BY D. Severson

14 Sep 2017

C:\Data\MWH\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Dwg 2-5_Ballard_GW Remedial Alt 2_MNA_ICs_14Sep2017.mxd



LEGEND:

- POST-MINE CONTOUR & ELEVATION, FEET
- POND OR LAKE
- STREAM – PERENNIAL
- STREAM – INTERMITTENT
- MINE PIT LOCATION (APPROXIMATE WHERE COVERED BY BACKFILL)
- WASTE ROCK DUMP LOCATION (APPROXIMATE)
- WASTE ROCK DUMP LOCATION OR PIT BACKFILL (APPROXIMATE)
- HIGHWAY
- ROAD
- RAILROAD
- P4 PRODUCTION HAUL ROAD (ACTIVE & INACTIVE)
- 0.05 TOTAL SELENIUM ISOCONCENTRATION CONTOUR (mg/L)
- 0.05 INFERRED TOTAL SELENIUM ISOCONCENTRATION CONTOUR (mg/L)
- P4 PRODUCTION PROPERTY BOUNDARY (APPROXIMATE)
- SECTION LINES
- 8 SECTION NUMBER
- BLM LANDS
- STATE LANDS
- OTHER PRIVATE LANDS

STATION TYPE:

- MSG = SPRING STATION
- MST = STREAM STATION
- MMW = GROUND WATER MONITORING WELL
- MBW = DIRECT PUSH MONITORING WELL INSTALLED IN 2008
- MBW = DIRECT PUSH MONITORING WELL INSTALLED IN 2009
- BH = 2008 DIRECT PUSH BOREHOLE
- BH = 2009 DIRECT PUSH BOREHOLE

KEY:

MMP = MINE PIT
MWD = WASTE ROCK DUMP

- BH043 0.01 — 2008 DIRECT PUSH BOREHOLE ID AND DISSOLVED SELENIUM CONCENTRATION
- BH043 0.01 — 2009 DIRECT PUSH BOREHOLE ID AND DISSOLVED SELENIUM CONCENTRATION
- <0.001 — CONCENTRATION LESS THAN THE METHOD DETECTION LIMIT

NOTES:

1. WHERE WELLS ARE NESTED IN THE ALLUVIAL FLOW SYSTEM (I.E. SHALLOW AND DEEPER) THE HIGHEST MEASURED CONCENTRATION IS USED FOR CONTOURING.
2. SPRING 2008 TOTAL SELENIUM CONCENTRATIONS ARE USED FOR MONITORING WELLS, SPRINGS AND HEADWATER STREAMS WHERE APPROPRIATE.
3. ISOCONCENTRATION CONTOUR INTERVAL=LOG WITH SUPPLEMENTAL HALF CYCLE CONTOURS.
4. BEDROCK WELLS ARE SHOWN FOR REFERENCE. SELENIUM CONCENTRATIONS ARE NOT SHOWN FOR THESE WELLS.

ISSUE/REV	DESCRIPTION	TECH	ENG	DATE
0	ISSUED DRAFT FOR CLIENT REVIEW	CHF	CLF	

DISCLAIMER:
THIS DRAWING WAS DEVELOPED THROUGH THE APPLICATION OF PROFESSIONAL ENGINEERING SKILL AND PROPRIETARY METHODOLOGIES, PROCESSES AND KNOW HOW OF MWH AS AUTHOR ALL PURSUANT TO THE TERMS OF A CONTRACTUAL SCOPE OF WORK GOVERNING ITS PREPARATION. THIS DRAWING MAY NOT BE USED OR MODIFIED OTHER THAN IN STRICT ACCORDANCE WITH THE TERMS OF THE GOVERNING CONTRACT AND SCOPE OF WORK OR OTHERWISE ABSENT THE INVOLVEMENT AND CONSENT OF THE AUTHOR. ANY ALTERATION OR ADAPTATION OF THIS DRAWING SHALL BE CONSISTENT WITH THE AUTHOR'S CONTRACTUAL AND PROPRIETARY RIGHTS AND BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY OF MWH.

DRAWING REFERENCE(S):
1. POST-MINE TOPOGRAPHY GENERATED FROM:
- USGS DIGITAL ELEVATION MODELS (DEM)–24K.
- SURVEY DATA FOR BALLARD MINE PROVIDED BY OLYMPUS AERIAL SURVEYS, INC. DATED: JUNE 2005.
- SURVEY DATA FOR HENRY MINE AREA PROVIDED BY OLYMPUS AERIAL SURVEYS, INC. DATED: NOVEMBER 2008.
- SURVEY DATA FOR ENOCH VALLEY MINE AREA PROVIDED BY P4 PRODUCTION DATED: DECEMBER 2007.
- US CENSUS BUREAU 2007 TIGER LINE DATA

PROJECTION: STATE PLANE COORDINATE SYSTEM
ZONE: IDAHO EAST
HORIZONTAL DATUM: NAD27
VERTICAL DATUM: NGVD29
UNITS: U.S. FEET

DESIGNED BY	C FOULK	09/17/13
DRAWN BY	C FOWLER	09/17/13
CHECKED BY	C FOULK	09/17/13
APPROVED BY	C FOULK	09/17/13
PROJECT MANAGER	V DRAIN	
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

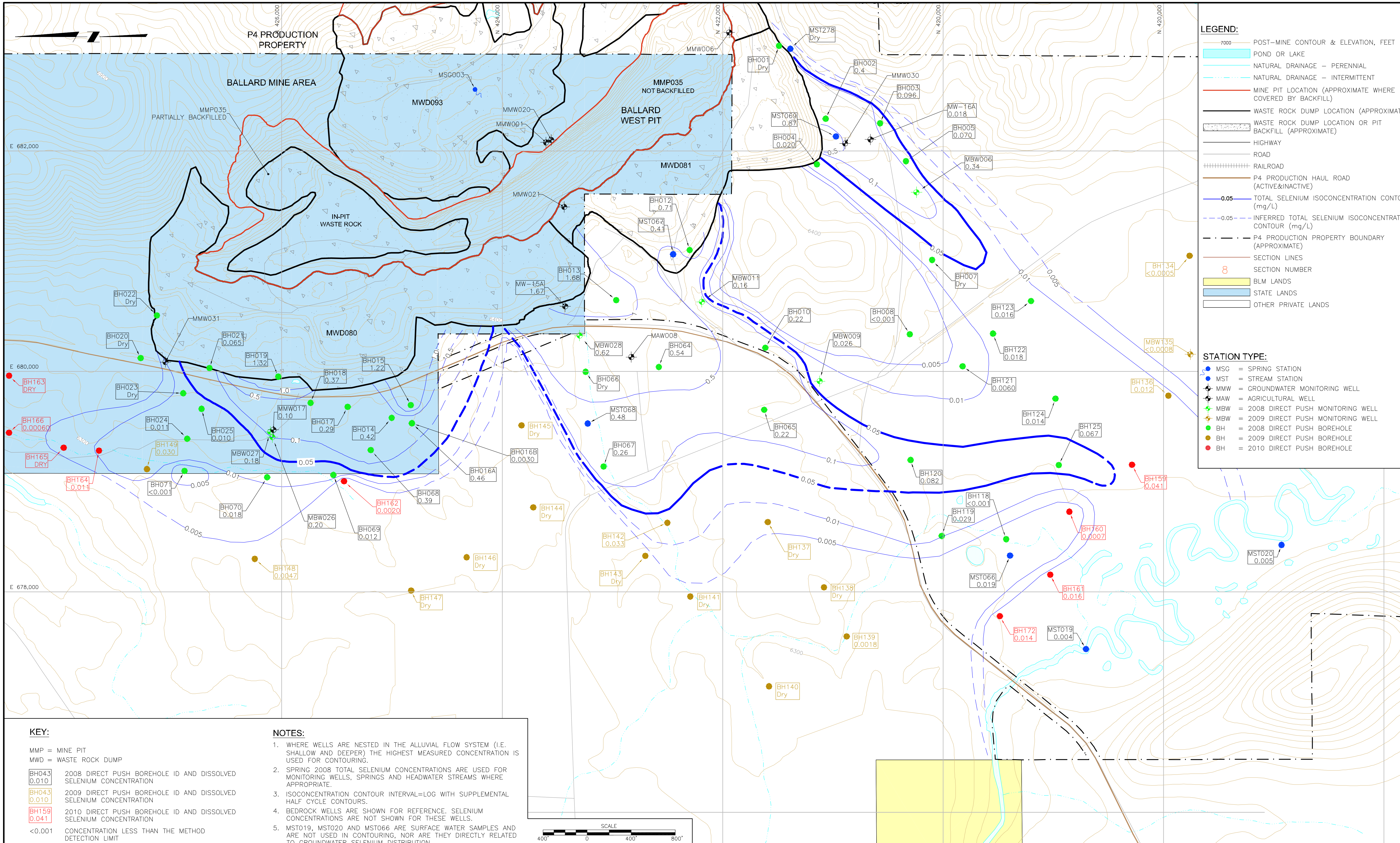
P4 Production, LLC

PROJECT LOCATION: BALLARD MINE SITE
PROJECT: BALLARD MINE MNA MEMO
TITLE: EAST SIDE OF MINE DIRECT PUSH SELENIUM ISOCONCENTRATION MAP

Stantec

DRAWING: 2-6
REVISION: 0
FILE NAME: 10502806D013-F

15 Sep 2017
C:\Data\MWH\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Fig 2-6_East Side Direct Push Selenium Iso Map_15Sep2017.ai



LEGEND:

- 7000 POST–MINE CONTOUR & ELEVATION, FEET
- POND OR LAKE
- NATURAL DRAINAGE – PERENNIAL
- NATURAL DRAINAGE – INTERMITTENT
- MINE PIT LOCATION (APPROXIMATE WHERE COVERED BY BACKFILL)
- WASTE ROCK DUMP LOCATION (APPROXIMATE)
- WASTE ROCK DUMP LOCATION OR PIT BACKFILL (APPROXIMATE)
- HIGHWAY
- ROAD
- RAILROAD
- P4 PRODUCTION HAUL ROAD (ACTIVE&INACTIVE)
- 0.05 TOTAL SELENIUM ISOCONCENTRATION CONTOUR (mg/L)
- 0.05 INFERRED TOTAL SELENIUM ISOCONCENTRATION CONTOUR (mg/L)
- P4 PRODUCTION PROPERTY BOUNDARY (APPROXIMATE)
- SECTION LINES
- 8 SECTION NUMBER
- BLM LANDS
- STATE LANDS
- OTHER PRIVATE LANDS

STATION TYPE:

- MSG = SPRING STATION
- MST = STREAM STATION
- MMW = GROUNDWATER MONITORING WELL
- MAW = AGRICULTURAL WELL
- MBW = 2008 DIRECT PUSH MONITORING WELL
- MBW = 2009 DIRECT PUSH MONITORING WELL
- BH = 2008 DIRECT PUSH BOREHOLE
- BH = 2009 DIRECT PUSH BOREHOLE
- BH = 2010 DIRECT PUSH BOREHOLE

KEY:

MMP = MINE PIT
MWD = WASTE ROCK DUMP

- BH043 0.010 — 2008 DIRECT PUSH BOREHOLE ID AND DISSOLVED SELENIUM CONCENTRATION
- BH043 0.010 — 2009 DIRECT PUSH BOREHOLE ID AND DISSOLVED SELENIUM CONCENTRATION
- BH159 0.041 — 2010 DIRECT PUSH BOREHOLE ID AND DISSOLVED SELENIUM CONCENTRATION
- <0.001 — CONCENTRATION LESS THAN THE METHOD DETECTION LIMIT

NOTES:

1. WHERE WELLS ARE NESTED IN THE ALLUVIAL FLOW SYSTEM (I.E. SHALLOW AND DEEPER) THE HIGHEST MEASURED CONCENTRATION IS USED FOR CONTOURING.
2. SPRING 2008 TOTAL SELENIUM CONCENTRATIONS ARE USED FOR MONITORING WELLS, SPRINGS AND HEADWATER STREAMS WHERE APPROPRIATE.
3. ISOCONCENTRATION CONTOUR INTERVAL=LOG WITH SUPPLEMENTAL HALF CYCLE CONTOURS.
4. BEDROCK WELLS ARE SHOWN FOR REFERENCE. SELENIUM CONCENTRATIONS ARE NOT SHOWN FOR THESE WELLS.
5. MST019, MST020 AND MST066 ARE SURFACE WATER SAMPLES AND ARE NOT USED IN CONTOURING, NOR ARE THEY DIRECTLY RELATED TO GROUNDWATER SELENIUM DISTRIBUTION.

ISSUE REV	DESCRIPTION	TECH	ENG	DATE
0	ISSUED DRAFT FOR CLIENT REVIEW	CHF	CLF	

DISCLAIMER:
THIS DRAWING WAS DEVELOPED THROUGH THE APPLICATION OF PROFESSIONAL ENGINEERING SKILL AND PROPRIETARY METHODOLOGIES, PROCESSES AND KNOW HOW OF MWH AS AUTHOR ALL PURSUANT TO THE TERMS OF A CONTRACTUAL SCOPE OF WORK GOVERNING ITS PREPARATION. THIS DRAWING MAY NOT BE USED OR MODIFIED OTHER THAN IN STRICT ACCORDANCE WITH THE TERMS OF THE GOVERNING CONTRACT AND SCOPE OF WORK OR OTHERWISE ABSENT THE INVOLVEMENT AND CONSENT OF THE AUTHOR. ANY ALTERATION OR ADAPTATION OF THIS DRAWING SHALL BE CONSISTENT WITH THE AUTHOR'S CONTRACTUAL AND PROPRIETARY RIGHTS AND BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY OF MWH.

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- SURVEY DATA FOR ENOCH VALLEY MINE AREA PROVIDED BY P4 PRODUCTION DATED: DECEMBER 2007.
- US CENSUS BUREAU 2007 TIGER LINE DATA

PROJECTION:
STATE PLANE COORDINATE SYSTEM
ZONE:
IDAHO EAST
HORIZONTAL DATUM:
NAD27
VERTICAL DATUM:
NGVD29
UNITS:
U.S. FEET

DESIGNED BY	C FOULK	09/17/13
DRAWN BY	C FOWLER	09/17/13
CHECKED BY	C FOULK	09/17/13
APPROVED BY	C FOULK	09/17/13
PROJECT MANAGER	V DRAIN	
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

P4 Production, LLC

PROJECT LOCATION: BALLARD MINE SITE

PROJECT: BALLARD MINE MNA MEMO

TITLE: WEST SIDE OF MINE DIRECT PUSH SELENIUM ISOCONCENTRATION MAP

Stantec

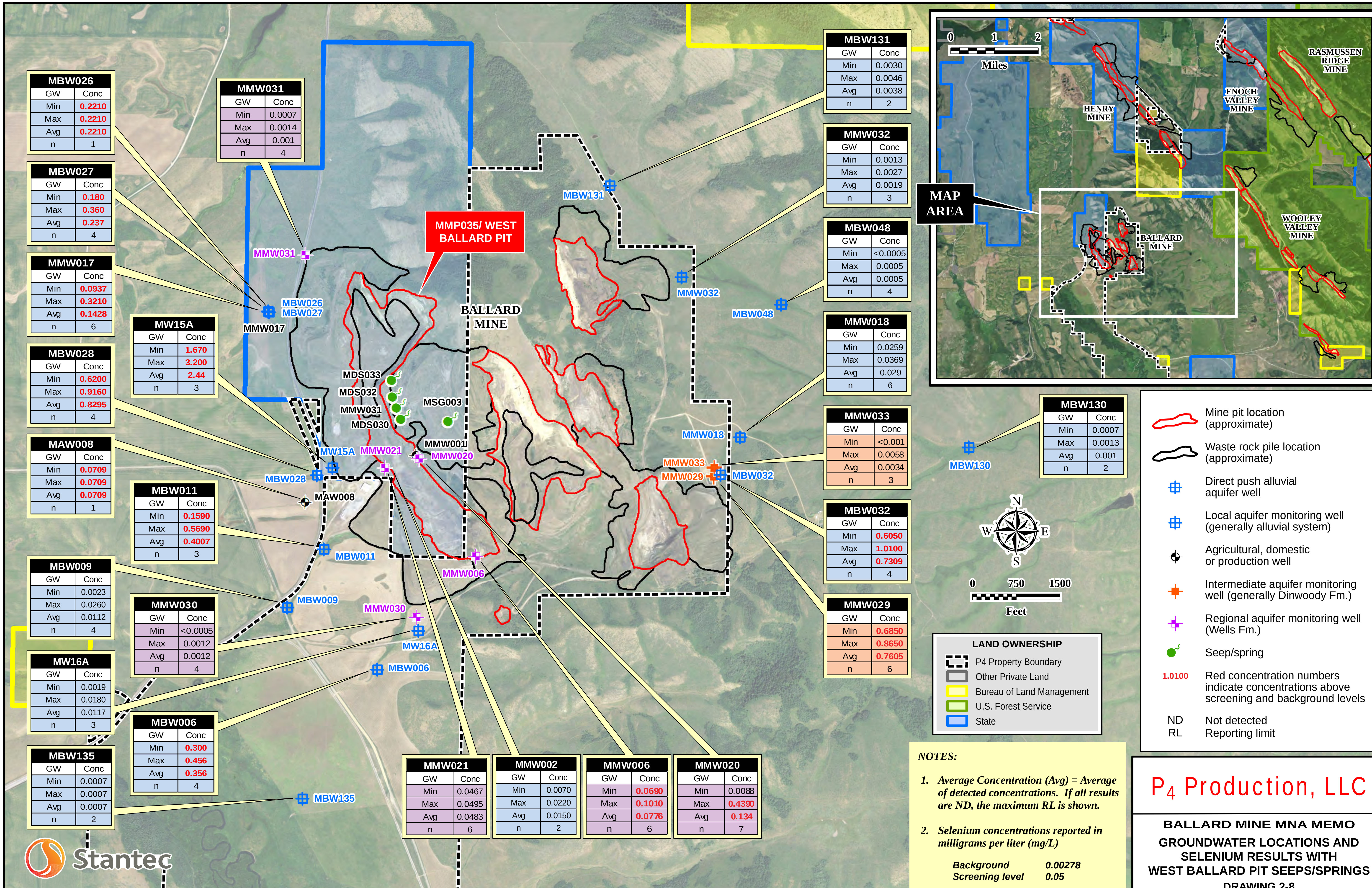
DRAWING: 2-7

REVISION: 0

FILE NAME: 10502806D014-F

C:\Data\MWH\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Fig 2-7_West Side Direct Push Selenium Iso Map_15Sep2017.ai

15 Sep 2017



MBW026	
GW	Conc
Min	0.2210
Max	0.2210
Avg	0.2210
n	1

MMW031	
GW	Conc
Min	0.0007
Max	0.0014
Avg	0.001
n	4

MBW027	
GW	Conc
Min	0.180
Max	0.360
Avg	0.237
n	4

MMW017	
GW	Conc
Min	0.0937
Max	0.3210
Avg	0.1428
n	6

MW15A	
GW	Conc
Min	1.670
Max	3.200
Avg	2.44
n	3

MBW028	
GW	Conc
Min	0.6200
Max	0.9160
Avg	0.8295
n	4

MAW008	
GW	Conc
Min	0.0709
Max	0.0709
Avg	0.0709
n	1

MBW011	
GW	Conc
Min	0.1590
Max	0.5690
Avg	0.4007
n	3

MBW009	
GW	Conc
Min	0.0023
Max	0.0260
Avg	0.0112
n	4

MMW030	
GW	Conc
Min	<0.0005
Max	0.0012
Avg	0.0012
n	4

MW16A	
GW	Conc
Min	0.0019
Max	0.0180
Avg	0.0117
n	3

MBW006	
GW	Conc
Min	0.300
Max	0.456
Avg	0.356
n	4

MBW135	
GW	Conc
Min	0.0007
Max	0.0007
Avg	0.0007
n	2

MMW021	
GW	Conc
Min	0.0467
Max	0.0495
Avg	0.0483
n	6

MMW002	
GW	Conc
Min	0.0070
Max	0.0220
Avg	0.0150
n	2

MMW006	
GW	Conc
Min	0.0690
Max	0.1010
Avg	0.0776
n	6

MMW020	
GW	Conc
Min	0.0088
Max	0.4390
Avg	0.134
n	7

MBW131	
GW	Conc
Min	0.0030
Max	0.0046
Avg	0.0038
n	2

MMW032	
GW	Conc
Min	0.0013
Max	0.0027
Avg	0.0019
n	3

MBW048	
GW	Conc
Min	<0.0005
Max	0.0005
Avg	0.0005
n	4

MMW018	
GW	Conc
Min	0.0259
Max	0.0369
Avg	0.029
n	6

MMW033	
GW	Conc
Min	<0.001
Max	0.0058
Avg	0.0034
n	3

MBW032	
GW	Conc
Min	0.6050
Max	1.0100
Avg	0.7309
n	4

MMW029	
GW	Conc
Min	0.6850
Max	0.8650
Avg	0.7605
n	6

MBW130	
GW	Conc
Min	0.0007
Max	0.0013
Avg	0.001
n	2

LAND OWNERSHIP

- P4 Property Boundary
- Other Private Land
- Bureau of Land Management
- U.S. Forest Service
- State

- Mine pit location (approximate)
- Waste rock pile location (approximate)
- Direct push alluvial aquifer well
- Local aquifer monitoring well (generally alluvial system)
- Agricultural, domestic or production well
- Intermediate aquifer monitoring well (generally Dinwoody Fm.)
- Regional aquifer monitoring well (Wells Fm.)
- Seep/spring
- 1.0100 Red concentration numbers indicate concentrations above screening and background levels
- ND Not detected
- RL Reporting limit

NOTES:

1. *Average Concentration (Avg) = Average of detected concentrations. If all results are ND, the maximum RL is shown.*
2. *Selenium concentrations reported in milligrams per liter (mg/L)*

Background	*0.00278*
Screening level	*0.05*

P4 Production, LLC

BALLARD MINE MNA MEMO

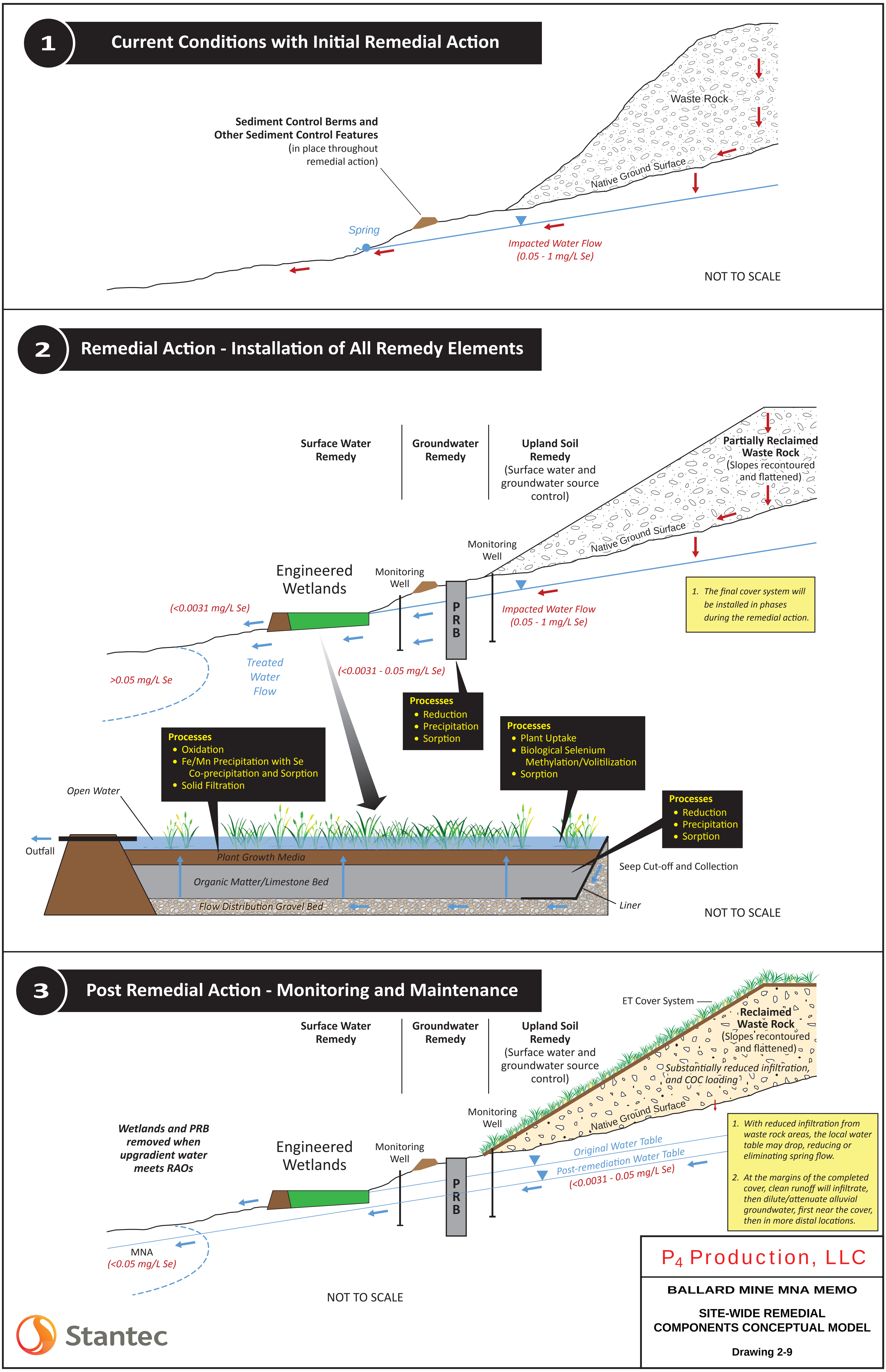
GROUNDWATER LOCATIONS AND SELENIUM RESULTS WITH WEST BALLARD PIT SEEPS/SPRINGS

DRAWING 2-8

J:\Industrial Projects\P4 Monsanto\P4 Monsanto\BALLARD_MNA_Jun2017\FIGURES\Dwg 2-8_Ballard_GW Locs and Selenium Results with West Ballard Pit Seeps_Springs_15Sep2017.mxd

15 Sep 2017

DRAWING BY D. Severson


1 Current Conditions with Initial Remedial Action
Waste Rock
Sediment Control Berms and Other Sediment Control Features (in place throughout remedial action)
Native Ground Surface
Spring
Impacted Water Flow (0.05 - 1 mg/L Se)
NOT TO SCALE
2 Remedial Action - Installation of All Remedy Elements
Surface Water Remedy
Groundwater Remedy
Upland Soil Remedy (Surface water and groundwater source control)
Partially Reclaimed Waste Rock (Slopes recontoured and flattened)
Native Ground Surface
Monitoring Well
Monitoring Well
Engineered Wetlands
(<0.0031 mg/L Se)
PRB
Impacted Water Flow (0.05 - 1 mg/L Se)
1. The final cover system will be installed in phases during the remedial action.
>0.05 mg/L Se
Treated Water Flow
(<0.0031 - 0.05 mg/L Se)
Processes
• Reduction
• Precipitation
• Sorption
Processes
• Plant Uptake
• Biological Selenium Methylation/Volitilization
• Sorption
Processes
• Oxidation
• Fe/Mn Precipitation with Se Co-precipitation and Sorption
• Solid Filtration
Processes
• Reduction
• Precipitation
• Sorption
Open Water
Outfall
Plant Growth Media
Organic Matter/Limestone Bed
Flow Distribution Gravel Bed
Seep Cut-off and Collection
Liner
NOT TO SCALE
3 Post Remedial Action - Monitoring and Maintenance
Surface Water Remedy
Groundwater Remedy
Upland Soil Remedy (Surface water and groundwater source control)
ET Cover System
Reclaimed Waste Rock (Slopes recontoured and flattened)
Substantially reduced infiltration, and COC loading
Native Ground Surface
Monitoring Well
Original Water Table
Post-remediation Water Table
(<0.0031 - 0.05 mg/L Se)
1. With reduced infiltration from waste rock areas, the local water table may drop, reducing or eliminating spring flow.
2. At the margins of the completed cover, clean runoff will infiltrate, then dilute/attenuate alluvial groundwater, first near the cover, then in more distal locations.
Wetlands and PRB removed when upgradient water meets RAOs
Engineered Wetlands
Monitoring Well
PRB
MNA (<0.05 mg/L Se)
NOT TO SCALE
Stantec
P4 Production, LLC
BALLARD MINE MNA MEMO
SITE-WIDE REMEDIAL COMPONENTS CONCEPTUAL MODEL
Drawing 2-9

APPENDIX A

COMMENTS AND COMMENT RESPONSE DOCUMENTS

APPENDIX A-1

A/T Comments on *P4's Ballard Mine Supplemental Technical Memorandum, Monitored Natural Attenuation Remedy for Groundwater, Draft Rev 0, July 2017*

Transmitted to P4 on August 22, 2017

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
IDAHO OPERATIONS OFFICE
950 West Bannock, Suite 900
Boise, Idaho 83702

August 22, 2017

Molly R. Prickett
Environmental Engineer
Monsanto Company
Soda Springs Operations
1853 Highway 34
Soda Springs, Idaho 83276

Re: A/T Comments on Supplemental Technical Memorandum, Monitored Natural Attenuation Remedy for Groundwater, Draft, Revision 0, July 2017.

Dear Ms. Prickett,

The Agencies and Tribes (A/T) have reviewed the above referenced deliverable (MNA Tech Memo), submitted pursuant to the Administrative Settlement Agreement and Order on Consent/Consent Order for Performance of Remedial Investigation and Feasibility Study at the Enoch, Henry, and Ballard Mine Sites in Southeastern Idaho (or 2009 AOC). The MNA Tech Memo was submitted in response to a request from the A/T to prepare a tech memo that consolidates the existing data, evaluations, and other lines of evidence that were considered during the FS and that led to selection of MNA as an ancillary element (or "polishing step") of the recommended combined remedy. This letter transmits comments and direction on this draft deliverable.

We will be available to discuss these comments in the coming weeks. Please contact me if you have questions. I can be reached at 208-378-5763 or electronically at tomten.dave@epa.gov.

Sincerely,

//s//

Dave Tomten
Remedial Project Manager

Enclosure

cc: Mike Rowe, IDEQ – Pocatello
Jeremy Moore, US FWS - Chubbuck
Kelly Wright, Shoshone Bannock Tribes

Colleen O’Hara, BLM – Pocatello
Sherri Stumbo, Forest Service – Pocatello (electronic version only)
Vance Drain, MWH (electronic version only)
Shannon Ansley, Shoshone Bannock Tribes (electronic version only)
Dennis Smith, CH2MHill (electronic version only)
Gary Billman, IDL – Pocatello (electronic version only)

Enclosure

Comments on Supplemental Technical Memorandum, Monitored Natural Attenuation Remedy for Groundwater, Draft, Revision 0, July 2017.

Suggestions for Reorganizing

1. Section 1 Introduction – move description of Site and location (the third paragraph of section 1.1) to Section 2 Background discussion.
2. Section 2 Background - include a new subsection with a concise description of the Site (Site location and Site Features maps), relevant RI findings (geology map, nature and extent of contamination [waste, soil, groundwater (including plumes from Section 3.1)]. Elaborate on aquifer characteristics including summary of recharge rates, aquifer conductivity, briefly name plume mitigation mechanisms including MNA. Retain Subsection 2.2 Description of Potential Receptors and Subsection 2.3 Components of Proposed Site-wide RA. The opening paragraph of section 2.3 should be expanded to include a high level overview of the remedial approach, such as additional text along the following lines:

    The proposed remedy for groundwater includes a combination of PRBs, MNA, and ICs for mine-influenced groundwater, in conjunction with source controls in the upland soil/waster rock. MNA will be used as a polishing step to address contamination that has already been released to shallow groundwater. MNA would rely on dilution and dispersion over time as the primary mechanisms to reduce the concentration of contaminants. Sorption of contaminants to aquifer materials is a secondary mechanism that is expected to reduce concentration of contaminants in the groundwater. Biological reduction, while not currently indicated, is also expected to be a secondary mechanism under future anticipated conditions. LTM would be conducted at strategic sampling locations in all groundwater contaminant plumes to track progress toward meeting cleanup levels.

3. In the section on Regulatory Basis for MNA, suggest adding some additional information from EPA guidance documents for context, and introduce how it applies to the site and the proposed remedy. Additional points to make and concepts to include are:

    (a) Give EPA definition of MNA:

    EPA defines the term "monitored natural attenuation," as:

    > *The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The 'natural attenuation processes' that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants." (EPA, 1999; page 3)*

    Present additional information from EPA guidance that is particularly relevant to proposed use of MNA at Ballard (including information on dispersion and dilution) from the 1999 MNA guidance (page 18) and 2015 guidance (section 2.2). These sections provide context and conditions for use of MNA, and for when dilution and dispersion may be considered as primary mechanisms. EPA's policy states that dilution and dispersion should not be the primary mechanisms for MNA, *but that they may be appropriate for polishing under certain conditions*:

Dilution and dispersion generally are not appropriate as primary MNA mechanisms because they reduce concentrations through dispersal of contaminant mass rather than destruction or immobilization of contaminant mass. *Dilution and dispersion may be appropriate as a "polishing step" for distal portions of a plume when an active remedy is being used at a site, source control is complete and appropriate land use and ground water use controls are in place. [emphasis in original] (EPA, 2015; p. 14)*

(b) The information presented elsewhere in the tech memo should be linked back to this policy context.

(c) Then, describe the potential MNA mechanisms for Se at the site:

Potential natural attenuation mechanisms for selenium include: (1) dilution and dispersion; (2) biological stabilization/immobilization (i.e., microbially-mediated reduction of selenite [Se^{+4}] and selenate [Se^{+6}] to elemental selenium [Se^0], with concomitant precipitation); and (3) sorption. In most soil/groundwater systems, sorption of the water-soluble oxyanion forms of selenium is typically modest, at best. Biological reduction requires anaerobic conditions and a supply of biodegradable organics to serve as the electron donor to drive selenite/selenate reduction (the electron acceptor). Then, briefly summarize the elements of the proposed site remedy, focusing on how it fits with the description of MNA by dilution/dispersion above.

(d) Suggest that it would also be useful to present EPA's recommended tiered, lines-of-evidence approach for evaluating MNA (e.g., as follows), and state that this approach will be developed for the site in the following sections (Section 3 and 4):

The 1999 MNA guidance (EPA, 1999) recommends a three- tiered evaluation approach to develop multiple lines of evidence for evaluation of MNA. The 2015 guidance (EPA, 2015; p. 26) revised this approach for evaluating MNA of inorganic constituents via the following four phases:

- Phase I: Demonstration that the groundwater plume is *not expanding*.[1]
- Phase II: Determination that the *mechanism and rate* of the attenuation process are sufficient.[2]
- Phase III: Determination that the *capacity* of the aquifer is sufficient to attenuate the mass of contaminant within the plume and the *stability* of the immobilized contaminant is sufficient to resist re-mobilization.[3]

---

[1] In the 1999 MNA guidance, this tier is described as: "Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. (In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration**. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood**.)" (emphasis added)

[2] In the 1999 MNA guidance, this tier is described as: "Hydrogeologic and geochemical data that can be used to demonstrate **indirectly** the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels. For example, characterization data may be used to quantify the rates of contaminant sorption, dilution, or volatilization, or to demonstrate and quantify the rates of biological degradation processes occurring at the site." (emphasis in original).

[3] In the 1999 MNA guidance, this tier is described as: "Data from field or microcosm studies (conducted in or with actual contaminated site media) which **directly** demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only)." (emphasis in original).

- Phase IV: Design of a *performance monitoring program* based on an understanding of the mechanism of the attenuation process, and establishment of contingency remedies tailored to site-specific characteristics. This phase in effect reflects recommendations in the 1999 MNA guidance, but consolidated into a single, additional phase.

4. In Section 3, suggest adding subsections discussing and evaluating dilution and dispersion in the alluvial and Wells Formation groundwaters (existing and future), to the extent practical. Discussion may draw from cover system modeling report for the project, and other information/data on inflow to or dispersion within the two groundwater bodies from (non-capped) areas up- and cross-gradient during a baseline condition as well as after remediation (for comparison), and elements of the CSM. We believe that these mechanisms may be important for this site, especially since they will always occur to some extent – in contrast to bio-reduction/immobilization of Se, which depends on hypothetical future changes in environmental conditions.
5. Other Section 3 text. Largely retain as-is (although see review comments below), but suggest (1) providing more discussion of the attenuation mechanisms associated with the various types of evidence, and (2) couching the discussion to clarify what attenuation is currently demonstrable versus what changes and mechanisms are expected to contribute to attenuation in the future, and why.
6. Section 4. Add more specificity to the data needs to be collected to support the determination that MNA is occurring and can be monitored. Be as definitive as possible in stating actual monitoring actions that will be taken.
7. Overall, avoid or minimize use of indecisive words like “appears”, “may”, “dominant”, “relatively”, “some”, “suggests”, “substantially”, “strong(ly)”, “overwhelmingly”, and “might”. Keep the discussion concise and factual, recognizing that some lines of evidence are based on conceptual understanding.

References cited under item #1 above

EPA. 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*. OSWER Directive 9200.4-17P, April 1999.

EPA. 2007. *Monitored Natural Attenuation of Inorganic Contaminants in Groundwater*. Volumes 1 and 2. EPA/600/R-07/140, October 2007.

EPA. 2015. *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites*. OSWER Directive 9283.1-36, August 2015.

General Comments

In general, the technical memorandum (TM) indicates that there is little evidence for natural attenuation of selenium (Se) at the site *under existing conditions*, with the exception of a few isolated locations (monitoring wells). As written, the lines of evidence cited to support for use of MNA as part of the site remedy relies on creation of more favorable conditions for Se attenuation via biological reduction in the future as a result of the solids consolidation/grading, and capping parts of the remedy. It is suggested that the TM could be more compelling if it more clearly acknowledged this concept and expanded upon it by more thoroughly describing mechanisms, expected changes, and how they would affect attenuation processes. In addition, as noted above, the tech memo should more fully discuss dilution and dispersion as important mechanisms for reducing the concentration of Se in existing plumes over time (several decades).

Specific Comments

1. P. 2-6; COC source would be significantly reduced (rather than "substantially removed").

2. P. 2-6; A 10-fold reduction in net infiltration is cited. A more complete and quantitative summary of modeled cover system performance relative to modeled baseline condition should be provided. This information, along with expected performance of PRBs provides important context for understanding that MNA is a polishing step (or ancillary component) of the overall remedy.

3. P. 2-7; PRBs are intended to remove COCs in shallow GW, and provide reduction in concentration of contaminants transported further downgradient. The phrase "*likely will be robust*" is confusing and should be re-written to more clearly explain the conceptual model. The probable reduction of COCs in waters beyond the PRBs along with the reduction of precipitation infiltration through the waste rock caused by the ET caps would ultimately help reduce COC concentration in the alluvial aquifer.

4. P. 3-1; Present facts/data that upwelling a groundwater from Dinwoody Formation has been measured/verified, and sampling data indicates that water is free of COCs.

5. P. 3-4; Expand on the "compartmentalization" hypothesis to support point (reference pertinent Figures).

6. P. 3-6 and 3-7, text under "Trends in concentrations/plume stability" subheading. This subsection concludes that the Se plumes in the alluvial aquifer are static or very slowly advancing at most locations, and that this is evidence of Se attenuation. There are two ways of assessing plume status (i.e., as expanding, shrinking, or stable):
   (a) Evaluate concentrations versus time at individual monitoring wells (MWs) within the plume. This is a standard approach and is what Stantec has done. This approach provides an indication of plume status and attenuation, but doesn't definitively assess whether a plume is physically expanding or not. Also, consider doing statistical analysis of data trends in the TM or propose as part of the implementation plan.
   (b) Evaluate the length and/or areal extent of a plume over time. This approach directly assesses whether a plume is physically expanding, and this apparently has not been done. The TM acknowledges that more MWs are needed around the leading edges of the plume, and we agree that these are needed to complete the evaluation of plume status and effectiveness of MNA.
   (c) Consider whether other data exists (RI or otherwise) that can support the claim the plume extent is not increasing/concentrations are not rising (i.e. stable). If available, please present.
   (d) Site remedy includes monitoring the anticipated reduction of COC concentrations as a result of implemented remedial components (PRBs, ET cover) taking into account natural attenuation potential. Both MMW030 and MMW031 ***exhibit*** background selenium concentrations and ***suggest*** selenium contamination in the Wells Formation aquifer is confined to the Site near the West Ballard Pit and the seep and spring source. Please re-phrase for clarity.

7. P. 3-8, "Evaluation of Se/SO4 ratios" subheading (and others). Editorial note: some of this type of subsection headings are in bold type and others are not. Suggest making them bold to be consistent and also highlight the new subsections to the reader.

8. P. 3-8 through 3-10, text in subsection entitled Data that Support Attenuation, and under subheading entitled "Evaluation of Se/SO4 ratios".. This subsection states that measured Se/SO4

ratios indicate a lack of Se attenuation at most MWs in the alluvial groundwater plumes, but attempts to explain why attenuation is not observed and argues that this situation will change in the future after solids consolidation and capping are completed because those actions will create more conducive conditions for Se attenuation (i.e., via bio-reduction of oxidized Se forms). Clarify that the data shows that this mechanism is not occurring presently. Rather, it is a statement of expectations based on a conceptual model for future conditions. Consider a new subsection to distinguish between existing data and lines of evidence that support attenuation and other lines of evidence (such as changes in expected conditions) that support use of MNA. Methods or approaches to evaluation of MNA mechanisms and effectiveness should be outlined in Section 4.

9. P. 3-10, "Chemical Properties Relevant to MNA" subheading. Suggest that a thorough suite of MNA-related parameters be measured during the additional alluvial groundwater sampling during pre-design studies, not just the four parameters specified (Se, SO4, DO and ORP).

10. P. 3-12, "Blackfoot River – Southwestern Alluvial Plume Natural Attenuation" subheading. Again, this argument is somewhat speculative, or anecdotal, at present. Demonstration of MNA in the future will likely require more effort to evaluate and document the attenuation mechanism(s) and efficacy. Please present this interpretation as a hypothesis, and acknowledge and disclose uncertainty.

11. P. 3-12, "Contaminant Trends" subheading, last paragraph. The statement about the response at MMW006 and MMW021 to elevated Se concentrations at MMW020 does not appear to be well-supported by the data in Figure 3-3; in fact, it is difficult to discern any clear relationship between those data sets. A different possible interpretation of the data for MMW006 is that they seem to have an increasing trend. This is not mentioned in a discussion of plume stability like that presented for alluvial groundwater. If this trend were considered an indication of a potentially expanding plume (e.g., since a lack of an increasing concentration trend is taken to suggest a static plume and attenuation earlier in the TM for the alluvial groundwater), would that call into question the statement on p. 3-6 concluding that the data for MMW030 suggest that Se contamination in the Wells Formation groundwater is confined near the West Ballard Pit? Please present this interpretation as a hypothesis, and acknowledge and disclose uncertainty.

12. P. 3-14. This subsection acknowledges that literature and data from nearby phosphate mines pertaining to the Wells Formation (Table 3-2) indicate generally moderate to weak attenuation capacity for Se in the Wells Formation, and then goes on to suggest that future remedial actions will tend to create conditions more conducive for MNA. Similar to comment 3 above, although the concepts presented may be valid, this is more of a statement of future expectations rather than an existing line-of-evidence. Also, is there any way to tease out, from the original literature sources, how much of the reported Se attenuation was due to sorption versus dilution and dispersion?

13. P. 3-15 and 3-16, "Evaluation of Se:SO4 ratios" subheading. This subsection: (a) starts off by stating the "most of the impacted Wells Formation monitoring wells do not currently show evidence of attenuation, with an exception in MMW020"; (b) then describes how the Se:SO4 ratio data provide evidence of Se attenuation at MMW020; (c) then suggests that the evidence for Se attenuation at MMW020 indicates that Se can occur elsewhere in the Wells Formation; (d) then wraps up by concluding that "it appears that once the source is controlled, MNA will be immediately effective in

the aquifer closest to the source". This conclusion is only valid if actions that control the source also create conditions conducive for Se attenuation (i.e., microbial Se reduction). While solids consolidation and capping may reduce DO and ORP, it is not clear that they will enhance the supply of organic carbon to favor bio-reduction, particularly if the supply of organic carbon at MMW020 is due to the cause cited in the same paragraph (i.e., "infiltrating seep/spring water contains some dissolved organic content after infiltrating through waste rock and debris in the pit bottom, and this enhances biological activity"). Won't the earthwork (grading) and solids cover be designed to eliminate such infiltration of seep/spring water? Also, the conclusion quoted above is silent about MNA distal from the source – isn't this were the remedy intends for MNA to function?

14. P. 3-16; The statement MNA will be "immediately effective" once the source is controlled is speculative at this point. Please adjust.

15. P. 3-18, 1st sentence. This sentence is missing a word, such as "for" between "Site" and "the".

16. P. 3-19, 1st bullet. See specific comment 1 above.

17. P. 4-1, Pre-Design Studies and Aquifer Material Characterization sections. Suggest that any treatability testing designed to evaluate Se attenuation potential consider both existing conditions and projected future conditions.

APPENDIX A-2

P4 Responses to A/T Comments (dated August 22, 2017) on *P4's Ballard Mine Supplemental Technical Memorandum, Monitored Natural Attenuation Remedy for Groundwater, Draft Rev 0, July 2017*

Submitted to A/Ts on September 1, 2017

From: Drain, Vance <vance.drain@stantec.com>
Sent: Friday, September 01, 2017 12:44 PM
To: Tomten, Dave
Cc: MOLLY PRICKETT - P4 Monsanto (molly.prickett@monsanto.com); LEATHERMAN, CHRIS R [AG/1850]; RANDALL LEE COOPER - Monsanto/P4 (randall.lee.cooper@monsanto.com); Leah Wolf-Martin (leah@wolfmartininc.com); Cary Foulk (cfoulk@integrated-geosolutions.com)
Subject: P4's responses to A/T comments on the Ballard MNA Memorandum
Attachments: MNA Tech Memo P4 RTC for AT review (09-01-17).docx

Dave,
Attached are P4's responses to your comments submitted to P4 on 8-22-17 on the *Draft Supplemental MNA Memorandum for GW (i.e., MNA Memo)*. Currently, we are revising the *Draft MNA Memo* based on these comments (and our responses), but let us know if there are any problems with our interpretation of your requests. Please forward these responses to the other members of your A/T team as necessary for review and *////////*

Have a GREAT LABOR DAY WEEKEND!

Regards,

Vance

Vice President/Fellow Hydrogeologist
MWH, now part of Stantec
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A/T Comments and P4's Responses on Ballard Mine Feasibility Study (FS) Supplemental Technical Memorandum Monitored Natural Attenuation Remedy for Groundwater (Revision 0, July 2017)

Suggestions for Reorganizing

1. Section 1 Introduction – move description of Site and location (the third paragraph of section 1.1) to Section 2 Background discussion.

   P4 Response (RC-1)*: Agreed. As suggested, the site description and location information will be moved to Section 2.0.*

2. Section 2 Background - include a new subsection with a concise description of the Site (Site location and Site Features maps), relevant RI findings (geology map, nature and extent of contamination [waste, soil, groundwater (including plumes from Section 3.1)]. Elaborate on aquifer characteristics including summary of recharge rates, aquifer conductivity, briefly name plume mitigation mechanisms including MNA. Retain Subsection 2.2 Description of Potential Receptors and Subsection 2.3 Components of Proposed Site-wide RA. The opening paragraph of section 2.3 should be expanded to include a high level overview of the remedial approach, such as additional text along the following lines:

   > *The proposed remedy for groundwater includes a combination of PRBs, MNA, and ICs for mine-influenced groundwater, in conjunction with source controls in the upland soil/waster rock. MNA will be used as a polishing step to address contamination that has already been released to shallow groundwater. MNA would rely on dilution and dispersion over time as the primary mechanisms to reduce the concentration of contaminants. Sorption of contaminants to aquifer materials is a secondary mechanism that is expected to reduce concentration of contaminants in the groundwater. Biological reduction, while not currently indicated, is also expected to be a secondary mechanism under future anticipated conditions. LTM would be conducted at strategic sampling locations in all groundwater contaminant plumes to track progress toward meeting cleanup levels.*

   P4 Response (RC-2)*: Section 2.0 will be revised with new subsections, as needed, to include the information requested in the comment. These concise summaries will be developed from existing summaries in the Ballard Mine RI Report and Ballard Mine FS Memorandums. In addition, the Section 2.3 text will be added to the beginning of this section with the following proposed changes (new text in red):*

   > *"The proposed remedy for the Ballard Site groundwater includes a combination of PRBs, MNA, and ICs for mine-influenced groundwater, in conjunction with source controls in the upland soil/waste rock. MNA will be used as a polishing step to address contamination that has already been released to shallow groundwater. MNA for the Ballard Mine groundwater would rely on several mechanisms for attenuation of elevated constituents including dilution and dispersion, sorption of contaminants to aquifer materials over time, and biological reduction under future conditions ~~as the primary mechanisms to reduce the concentration of contaminants~~. It is anticipated that biological reduction, ~~while not~~ currently supported by limited data, would primarily occur near the source areas following the remedial action and along the Blackfoot River corridor. ~~Sorption of contaminants to aquifer materials is a secondary mechanism that is expected to reduce concentration of contaminants in the groundwater. Biological reduction,~~*

~~*while not currently indicated, is also expected to be a secondary mechanism under future anticipated conditions.*~~ *LTM would be conducted at strategic sampling locations in all groundwater contaminant plumes to track progress toward meeting cleanup levels."*

3. In the section on Regulatory Basis for MNA, suggest adding some additional information from EPA guidance documents for context, and introduce how it applies to the site and the proposed remedy. Additional points to make and concepts to include are:

(a) Give EPA definition of MNA:

EPA defines the term "monitored natural attenuation," as:

> *The reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The 'natural attenuation processes' that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants." (EPA, 1999; page 3)*

Present additional information from EPA guidance that is particularly relevant to proposed use of MNA at Ballard (including information on dispersion and dilution) from the 1999 MNA guidance (page 18) and 2015 guidance (section 2.2). These sections provide context and conditions for use of MNA, and for when dilution and dispersion may be considered as primary mechanisms. EPA's policy states that dilution and dispersion should not be the primary mechanisms for MNA, *but that they may be appropriate for polishing under certain conditions*:

> ***Dilution and dispersion generally are not appropriate as primary MNA mechanisms because they reduce concentrations through dispersal of contaminant mass rather than destruction or immobilization of contaminant mass.*** *Dilution and dispersion may be appropriate as a "polishing step" for distal portions of a plume when an active remedy is being used at a site, source control is complete and appropriate land use and ground water use controls are in place. [emphasis in original] (EPA, 2015; p. 14)*

P4 Response (RC-3a)*: Agreed. Additional text including the definition of MNA and the EPA's policy regarding dilution and dispersion will be included in the section on Regulatory Basis for MNA.*

(b) The information presented elsewhere in the tech memo should be linked back to this policy context.

P4 Response (RC-3b)*: Agreed. Other applicable text in the document will be linked to the EPA's policy, as necessary.*

(c) Then, describe the potential MNA mechanisms for Se at the site:

Potential natural attenuation mechanisms for selenium include: (1) dilution and dispersion; (2) biological stabilization/immobilization (i.e., microbially-mediated reduction of selenite [Se^{+4}] and selenate [Se^{+6}] to elemental selenium [Se^0], with concomitant precipitation); and (3) sorption. In most soil/groundwater systems, sorption of the water-soluble oxyanion forms of selenium is typically modest, at best. Biological reduction requires anaerobic conditions and a supply of biodegradable organics to serve as the electron donor to drive selenite/selenate reduction (the electron acceptor). Then, briefly summarize the elements of the proposed site remedy, focusing on how it fits with the description of MNA by dilution/dispersion above.

***P4 Response (RC-3c)**: A discussion of mechanisms for MNA of selenium (both general and site-specific) will be incorporated in into the new subsection of Section 3 as indicated in response to RC-4 below.*

(d) Suggest that it would also be useful to present EPA's recommended tiered, lines-of-evidence approach for evaluating MNA (e.g., as follows), and state that this approach will be developed for the site in the following sections (Section 3 and 4):

The 1999 MNA guidance (EPA, 1999) recommends a three- tiered evaluation approach to develop multiple lines of evidence for evaluation of MNA. The 2015 guidance (EPA, 2015; p. 26) revised this approach for evaluating MNA of inorganic constituents via the following four phases:

- Phase I: Demonstration that the groundwater plume is *not expanding*.[1]
- Phase II: Determination that the *mechanism and rate* of the attenuation process are sufficient.[2]
- Phase III: Determination that the *capacity* of the aquifer is sufficient to attenuate the mass of contaminant within the plume and the *stability* of the immobilized contaminant is sufficient to resist re-mobilization.[3]
- Phase IV: Design of a *performance monitoring program* based on an understanding of the mechanism of the attenuation process, and establishment of contingency remedies tailored to site-specific characteristics. This phase in effect reflects recommendations in the 1999 MNA guidance, but consolidated into a single, additional phase.

***P4 Response (RC-3d)**: Agreed. EPA's tiered evaluation approach will be incorporated into Section 2.0 and cross-referenced within applicable portions of Sections 3.0 and 4.0.*

4. In Section 3, suggest adding subsections discussing and evaluating dilution and dispersion in the alluvial and Wells Formation groundwaters (existing and future), to the extent practical. Discussion may draw from cover system modeling report for the project, and other information/data on inflow to or dispersion within the two groundwater bodies from (non-capped) areas up- and cross-gradient during a baseline condition as well as after remediation (for comparison), and elements of the CSM. We believe that these mechanisms may be important for this site, especially since they will always occur to some extent – in contrast to bio-reduction/immobilization of Se, which depends on hypothetical future changes in environmental conditions.

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[1] In the 1999 MNA guidance, this tier is described as: "Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. (In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration**. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood**.)" (emphasis added)

[2] In the 1999 MNA guidance, this tier is described as: "Hydrogeologic and geochemical data that can be used to demonstrate **indirectly** the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels. For example, characterization data may be used to quantify the rates of contaminant sorption, dilution, or volatilization, or to demonstrate and quantify the rates of biological degradation processes occurring at the site." (emphasis in original).

[3] In the 1999 MNA guidance, this tier is described as: "Data from field or microcosm studies (conducted in or with actual contaminated site media) which **directly** demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only)." (emphasis in original).

__P4 Response (RC-4)__: A new subsection will be added to Section 3.0 to discuss MNA mechanisms applicable to the Ballard Site plumes. This new subsection will include a discussion of dilution and dispersion, as well as, the biochemical and chemical processes.

5. Other Section 3 text. Largely retain as-is (although see review comments below), but suggest (1) providing more discussion of the attenuation mechanisms associated with the various types of evidence, and (2) couching the discussion to clarify what attenuation is currently demonstrable versus what changes and mechanisms are expected to contribute to attenuation in the future, and why.

   __P4 Response (RC-5)__: Per the previous response (RC-4), this discussion will be largely included in the new Section 3 subsection that discusses attenuation mechanism, but some components will be incorporated into other portions of Section 3, as needed.

6. Section 4. Add more specificity to the data needs to be collected to support the determination that MNA is occurring and can be monitored. Be as definitive as possible in stating actual monitoring actions that will be taken.

   __P4 Response (RC-6)__: Some additional detail will be added to Section 4, but P4 will provide specifics of the MNA investigation program in a standalone work plan (Pre-Design MNA SAP) associated with the remedial design process.

7. Overall, avoid or minimize use of indecisive words like “appears”, “may”, “dominant”, “relatively”, “some”, “suggests”, “substantially”, “strong(ly)”, “overwhelmingly”, and “might”. Keep the discussion concise and factual, recognizing that some lines of evidence are based on conceptual understanding.

   __P4 Response (RC-7)__: Use of these words have been reviewed on a case-by-case basis and revised as needed. Because these are complex natural systems, there will always be some uncertainty. We have attempted to be more definitive and/or qualify the uncertainty where it is possible.

References cited under item #1 above

EPA. 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*. OSWER Directive 9200.4-17P, April 1999.

EPA. 2007. *Monitored Natural Attenuation of Inorganic Contaminants in Groundwater*. Volumes 1 and 2. EPA/600/R-07/140, October 2007.

EPA. 2015. *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites*. OSWER Directive 9283.1-36, August 2015.

General Comments

In general, the technical memorandum (TM) indicates that there is little evidence for natural attenuation of selenium (Se) at the site *under existing conditions*, with the exception of a few isolated locations (monitoring wells). As written, the lines of evidence cited to support for use of MNA as part of the site remedy relies on creation of more favorable conditions for Se attenuation via biological reduction in the future as a result of the solids consolidation/grading, and capping parts of the remedy. It is suggested that the TM could be more compelling if it more clearly acknowledged this concept and expanded upon it by more thoroughly describing mechanisms, expected changes, and how they would affect attenuation processes. In addition, as noted above, the tech memo should more fully discuss dilution and dispersion as important mechanisms for reducing the concentration of Se in existing plumes over time (several decades).

__P4 Response (GC-1)__: Much of the information requested in this comment will be provided in the new subsection in Section 3.0 as indicated in response to RC-4.

Regarding the relationship to the grading and capping components of the remedy, the remedial actions taken in the waste rock areas will encourage attenuation primarily by reducing oxygen flux through the waste rock. It has been established that the biological reduction can occur in waste rock dumps containing the relatively high-carbon Meade Peak Member rocks (Hays, et al., 2016). This process can and will prevent selenium from being mobilized from the source waste rock, as well as, immobilize selenium that has already been released from near surface portions of a waste rock dump. . In the latter case, it is a form of plume attenuation in the most upgradient portion of the plume (i.e., within the source area).

Regardless, following installation of the cover systems, the chemistry of the groundwater emanating from beneath the waste rock areas will be transformed and will not be favorable for selenium dissolution. The groundwater leaving the covered waste rock area will be less oxygenated (reduced) and have lower concentrations of COCs. The blending of this source area groundwater with the upstream edges of the alluvial plumes will act to reduce concentration of the COCs through dilution, as well as, chemical reactions. Infiltration from the surface (i.e., precipitation and clean surface water running off the cover systems) will have a more discernable diluting effect on the intermediate and downgradient portions of the Site plumes.

This discussion will be included in in the new Section 3.0 subsection (response RC-4), and related text elsewhere in the memo will be edited to better reflect this concept.

Specific Comments

1. P. 2-6; COC source would be significantly reduced (rather than "substantially removed").

   ***P4 Response (SC-1)**: This revision will be made in the revised memorandum.*

2. P. 2-6; A 10-fold reduction in net infiltration is cited. A more complete and quantitative summary of modeled cover system performance relative to modeled baseline condition should be provided. This information, along with expected performance of PRBs provides important context for understanding that MNA is a polishing step (or ancillary component) of the overall remedy.

   ***P4 Response (SC-2)**: Additional text summarizing Golder's cover modeling and Stantec's evaluation of the modeling as documented in Appendix B of <u>Ballard Mine FS Memo #2</u>, <u>Cover System Evaluation Memorandum</u> (MWH, 2016b) will be included in Section 2.3.2.*

3. P. 2-7; PRBs are intended to remove COCs in shallow GW, and provide reduction in concentration of contaminants transported further downgradient. The phrase "*likely will be robust*" is confusing and should be re-written to more clearly explain the conceptual model. The probable reduction of COCs in waters beyond the PRBs along with the reduction of precipitation infiltration through the waste rock caused by the ET caps would ultimately help reduce COC concentration in the alluvial aquifer.

   ***P4 Response (SC-3)**: The 2nd sentence in paragraph 2 of Section 2.3.3 will be revised as follows (new text in red):*

   > *"Therefore, while the intent of the PRBs ~~are~~ is not to directly treat the entire alluvial groundwater plumes emanating from the upland source area, the reduction in COCs due to the PRBs, where installed,~~ likely will be robust enough to substantially~~ will significantly reduce transport of COCs into the alluvial plumes that are moving away from the source area (Drawings 2-1 and 2-2). Therefore, the PRBs will help facilitate ~~effectiveness of~~ MNA effectiveness early in the remedial action by reducing COC flux during the ~~interim~~ period between PRB installation, (early in the RA), up to the end of the upland soil/waste rock remedy (grading, consolidation, backfilling and installation of the ET cover system) and prior to substantial waste rock drain down (as discussed above)."*

4. P. 3-1; Present facts/data that upwelling a groundwater from Dinwoody Formation has been measured/verified, and sampling data indicates that water is free of COCs.

   P4 Response (SC-4)*: The upward gradient in the Dinwoody Formation has been verified through the installation of a nested well set, which verified the conceptual model explaining the prevalence of springs in that portion of the Site. The relevant sentence in the paragraph will be modified to read (new text in red):*

   > *"The Dinwoody Formation is not impacted at the Ballard Site, and in fact, where groundwater has been encountered in the Dinwoody Formation, it is a source of clean upwelling groundwater, as verified by the potentiometric and water quality conditions observed in nested well set MBW032/MMW029/MMW033 (refer to Ballard Mine RI Report for additional details)."*

5. P. 3-4; Expand on the "compartmentalization" hypothesis to support point (reference pertinent Figures).

   P4 Response (SC-5)*: Compartmentalization is a fact of the Ballard Site geology and regional/site specific faulting. The specific effects of compartmentalization on groundwater flow are less certain, but they do occur and a cross-section from the Ballard Mine RI Report will be included to illustrate this concept. The following text also will be added (new text in red):*

   > *"Examples of how the faulting and bedding compartmentalizes the Site is provided in cross-section on Drawing 3-2 (new drawing). Both faulting and folding can and do position high permeability beds of the Site's sedimentary units against lower permeability beds. In addition along the fault slip planes, fault gouge also can create low permeability barriers or in some instances high permeability conduits. The faults that create conduits can be locations of enhanced recharge from the surface or adjoining fault blocks, therefore, creating areas of higher hydraulic head along and adjacent to the faults. This elevated hydraulic head then can act as flow barriers. This has been observed along the southwest portion of the Site at MMW030 in the Wells Formation."* See response SC-11 for further related discussion. *The converse can also be true where a fault acts as a drain.*

6. P. 3-6 and 3-7, text under "Trends in concentrations/plume stability" subheading. This subsection concludes that the Se plumes in the alluvial aquifer are static or very slowly advancing at most locations, and that this is evidence of Se attenuation. There are two ways of assessing plume status (i.e., as expanding, shrinking, or stable):
   (a) Evaluate concentrations versus time at individual monitoring wells (MWs) within the plume. This is a standard approach and is what Stantec has done. This approach provides an indication of plume status and attenuation, but doesn't definitively assess whether a plume is physically expanding or not. Also, consider doing statistical analysis of data trends in the TM or propose as part of the implementation plan.

   P4 Response (SC-6a)*: Comment acknowledged. We propose that a more detailed statistical analysis of the monitoring well concentration trends be considered in the implementation plan. This will be added to the text of Section 4.0.*

   (b) Evaluate the length and/or areal extent of a plume over time. This approach directly assesses whether a plume is physically expanding, and this apparently has not been done. The TM acknowledges that more MWs are needed around the leading edges of the plume, and we agree that these are needed to complete the evaluation of plume status and effectiveness of MNA.

   P4 Response (SC-6b)*: The current placement of the monitoring network and duration of monitoring does not provide a means to evaluate changes in the plume length and extent over time. It is largely the observations of changes (or lack of changes) in COC concentrations in the plumes over time, which are presented in the memo. Observations show that the alluvial plume*

COC concentrations are largely stable with the exception of monitoring well MBW130 which is located downgradient of the largest plume on the east side of the Site. As shown on Figure 3-1, the concentrations in MBW130 exhibits background concentrations of selenium with a downward trend. This monitoring point will be specifically called out in current Section 3.2.1.

Another method for evaluating plume growth is comparison of observed plume extent with the predicted extent using aquifer properties. This evaluation is provided in the Ballard Mine RI Report and compares measured with back-calculated aquifer hydraulic conductivities. The range of back-calculated hydraulic conductivities based on age and length of the plumes was 0.89 to 7.0 feet/day with an average of 2.8 feet/day. This is compared to measured hydraulic conductivities that range from 1.4 to 20 feet/day, with an average of 3.3 feet/day.

These data suggest that the plumes have moved slower than is predicted based on the measured aquifer properties. However, with the uncertainty in the measured hydraulic conductivity data this evaluation is not conclusive (as discussed in the Ballard Mine RI Report) and will be further evaluated following collection of additional data during the pre-design studies.

(c) Consider whether other data exists (RI or otherwise) that can support the claim the plume extent is not increasing/concentrations are not rising (i.e. stable). If available, please present.

***P4 Response (SC-6c)**: The conclusion that the alluvial plumes are stable, or very slowly advancing, are largely supported by the concentrations trends found in the existing permanent well network, which it is acknowledged, is not strategically positioned along the plume edges (the exception is well MBW130 as discussed in the preceding comment). This data gap is acknowledged in the memo, and will be further reiterated in the revised memo.*

(d) Site remedy includes monitoring the anticipated reduction of COC concentrations as a result of implemented remedial components (PRBs, ET cover) taking into account natural attenuation potential. Both MMW030 and MMW031 ***exhibit*** background selenium concentrations and ***suggest*** selenium contamination in the Wells Formation aquifer is confined to the Site near the West Ballard Pit and the seep and spring source. Please re-phrase for clarity.

***P4 Response (SC-6d)**: The sentence will be revised as follows (new text in red):*

> *"Both MMW030 and MMW031 exhibit background selenium concentrations and indicate that selenium contamination in the Wells Formation aquifer has not migrated to the southwest or northwest. This combined with the geologic and topographic configuration of the Site supports that impacted groundwater within the Wells Formation is largely confined within the Site, near the West Ballard Pit and the seep and spring source."*

7. P. 3-8, "Evaluation of Se/SO4 ratios" subheading (and others). Editorial note: some of this type of subsection headings are in bold type and others are not. Suggest making them bold to be consistent and also highlight the new subsections to the reader.

   ***P4 Response (SC-7)**: Formatting will be checked and corrected to highlight these subsections in a consistent manner in the revised draft final memorandum.*

8. P. 3-8 through 3-10, text in subsection entitled Data that Support Attenuation, and under subheading entitled "Evaluation of Se/SO4 ratios". This subsection states that measured Se/SO4 ratios indicate a lack of Se attenuation at most MWs in the alluvial groundwater plumes, but attempts to explain why attenuation is not observed and argues that this situation will change in the future after solids consolidation and capping are completed because those actions will create more conducive conditions for Se attenuation (i.e., via bio-reduction of oxidized Se forms). Clarify that the data shows that this mechanism is not occurring presently. Rather, it is a statement of expectations based on a conceptual model for future conditions. Consider a new subsection to distinguish between existing data and lines of evidence that support attenuation and other lines of evidence

(such as changes in expected conditions) that support use of MNA. Methods or approaches to evaluation of MNA mechanisms and effectiveness should be outlined in Section 4.

P4 Response (SC-8)*: The text will be reorganized to better segregate the existing data presentation from the explanation of how reclamation will affect future MNA conditions (anticipated future conditions and MNA in the site conceptual model). Additional methods/approaches to evaluate current and future MNA mechanisms and effectiveness will be included in Section 4.*

9. P. 3-10, "Chemical Properties Relevant to MNA" subheading. Suggest that a thorough suite of MNA-related parameters be measured during the additional alluvial groundwater sampling during pre-design studies, not just the four parameters specified (Se, SO4, DO and ORP).

P4 Response (SC-9)*: The sentence will be modified to include the following (new text in red):*

> *"……, as well as, general water quality parameters, total organic carbon, ferrous/ferric iron, selenium species, and other trace metal and non-metals, ………"*

10. P. 3-12, "Blackfoot River – Southwestern Alluvial Plume Natural Attenuation" subheading. Again, this argument is somewhat speculative, or anecdotal, at present. Demonstration of MNA in the future will likely require more effort to evaluate and document the attenuation mechanism(s) and efficacy. Please present this interpretation as a hypothesis, and acknowledge and disclose uncertainty.

P4 Response (SC-10)*: The selenium attenuation in the wetlands adjacent to the Blackfoot River is presented as an alternative to explain why loading from one of the western groundwater plumes is not observed in the Blackfoot River. The text already identifies the process as hypothetical without supporting data – "Currently, there has been no quantification or verification of this hypothesis, but an evaluation of this potential component of MNA are presented in the pre-design studies, as discussed in Section 4.0." The intent of the paragraph was to identify a natural attenuation process potentially active at the Site that needs verification. No additional changes to the text are proposed.*

11. P. 3-12, "Contaminant Trends" subheading, last paragraph. The statement about the response at MMW006 and MMW021 to elevated Se concentrations at MMW020 does not appear to be well-supported by the data in Figure 3-3; in fact, it is difficult to discern any clear relationship between those data sets. A different possible interpretation of the data for MMW006 is that they seem to have an increasing trend. This is not mentioned in a discussion of plume stability like that presented for alluvial groundwater. If this trend were considered an indication of a potentially expanding plume (e.g., since a lack of an increasing concentration trend is taken to suggest a static plume and attenuation earlier in the TM for the alluvial groundwater), would that call into question the statement on p. 3-6 concluding that the data for MMW030 suggest that Se contamination in the Wells Formation groundwater is confined near the West Ballard Pit? Please present this interpretation as a hypothesis, and acknowledge and disclose uncertainty.

P4 Response (SC-11)*: Interpreting data for the Wells Formation is difficult, because, as stated in the memo, the monitoring wells are installed within different stratigraphic levels in the Wells Formation and in some cases are separated by faults. However, the statement regarding the response in selenium concentrations in MMW006 also is based on other data presented in the <u>Ballard Mine RI Report</u>. Based on geological and potentiometric data, only MMW006 and MMW021 appear to be in a similar hydrogeologic unit as detailed in Section 5.1.5.4 of the <u>Ballard Mine RI Report</u> (Figure 5-1 attached below). Each of the Ballard Site wells installed in the Wells Formation monitoring network responded to the large 2011 recharge event and provided some important information regard the hydrogeology of this deeper aquifer.*

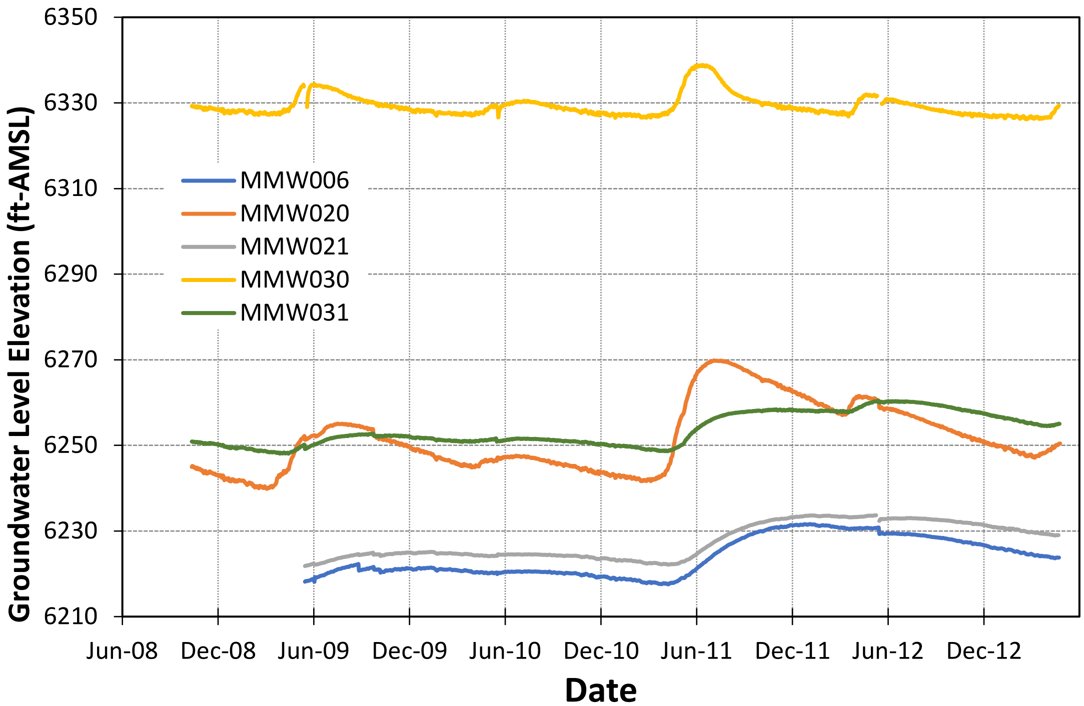
In summary, it was observed that monitoring wells MMW006 and MMW021 are hydraulically downgradient from MMW020, which is directly affected by the contaminated spring and seep *discharge and exhibits strong responses to increased recharge (e.g., the discharge event in the spring). The potentiometric response to recharge is more attenuated and delayed in MMW006 and MMW021. The response to the 2011 recharge event in MMW031 was similar to MMW006 and MMW021, but the absolute head in MMW031 is similar to MMW020. MMW030 is positioned upgradient of the other Wells Formation wells and is located just above a fault that appears to be a significant recharge zone. It has been concluded that the generally east-west trending subordinate faults, which may be conjugate or parallel to the Blackfoot Fault, represent an upgradient flow boundary within the Wells Formation. (Please note that the fault and an apparent breccia zone was encountered on the bottom of the MMW030 drill hole. That portion of the drill hole was grouted, and the well was installed in the Wells Formation above the breccia zone.)*

Based on this information, conclusions relevant to the comment are:

- *It is reasonable, and even probable, that both MMW006 and MMW021, respond to increases in concentrations observed at MMW020 in a more delayed manner as flow has be transported across lower permeability bedding within the formation. The new cross-section that will be added to the memo will be used to help illustrated this concept of cross bedding flow (new Drawing 3-2, see response SC-5).*
- *No other Site modifications have occurred in the last 40 or more years that would readily explain a now increasing trend in MMW006 concentrations. The most logical explanation is a response to increased infiltration, similar to what is observed in MMW020; however, in a more muted fashion, as would be any related future downward trend in concentrations.*
- *A muted response to change in potentiometric and chemical conditions would be expected because transport across lithologic bedding is expected to be much more limited, even though, the stratigraphic (along the bedding plane) distance may be relatively close (e.g., 100-150 feet).*
- *The source of contamination detected at MMW006 is likely the seeps and springs that affect MMW020 (although it could also be another undefined local source of affected infiltration) and the proposed preferred alternative would still significantly reduce and control the sources of contamination to the Wells Formation. Including unseen infiltration, by rerouting the spring water and covering the adjacent waste rock.*
- *Because of MMW030 location in a recharge area for the Wells Formation, it is clear that the contamination at the West Ballard Pit is confined in that direction. The same is true for the MMW031, but less strongly.*

It was not our intention to bog down the MNA memorandum with details from the Ballard Mine RI Report, but provide them were necessary to support specific conclusion. The conclusions listed above related to MMW006 and MMW021 will be included in the text to support the statement that changes in concentrations in MMW006 are related to changes in MMW020. Readers will be referred to the Ballard Mine RI Report for the data supporting the conclusions. It also should be noted that the regional conceptual hydrogeologic model for the area concludes that flow from the Wells Formation at the Ballard Site ultimately travels north-northwest to the Henry Springs, approximately 6.0 miles from the mine. This is the closest known discharge point for impacted Wells Formation water from the Ballard Site.

Figure 5-1 Piezometric Data for Wells Formation Monitoring Wells in the Western Ballard Mine Area



12. P. 3-14. This subsection acknowledges that literature and data from nearby phosphate mines pertaining to the Wells Formation (Table 3-2) indicate generally moderate to weak attenuation capacity for Se in the Wells Formation, and then goes on to suggest that future remedial actions will tend to create conditions more conducive for MNA. Similar to comment 3 above, although the concepts presented may be valid, this is more of a statement of future expectations rather than an existing line-of-evidence. Also, is there any way to tease out, from the original literature sources, how much of the reported Se attenuation was due to sorption versus dilution and dispersion?

    ***P4 Response (SC-12)**: See response to SC-8 regarding reorganization of the memo to discuss MNA processes based on current versus potential future conditions. Also, as noted in Table 3-2, the data are a mixture of batch tests and empirical data from the Smoky Canyon site. The batch test results are obviously largely from sorption. The empirical data must include components of dilution and dispersion, but this was not distinguished in the data.*

13. P. 3-15 and 3-16, "Evaluation of Se:SO4 ratios" subheading. This subsection: (a) starts off by stating the "most of the impacted Wells Formation monitoring wells do not currently show evidence of attenuation, with an exception in MMW020"; (b) then describes how the Se:SO4 ratio data provide evidence of Se attenuation at MMW020; (c) then suggests that the evidence for Se attenuation at MMW020 indicates that Se can occur elsewhere in the Wells Formation; (d) then wraps up by concluding that "it appears that once the source is controlled, MNA will be immediately effective in the aquifer closest to the source". This conclusion is only valid if actions that control the source also create conditions conducive for Se attenuation (i.e., microbial Se reduction). While solids consolidation and capping may reduce DO and ORP, it is not clear that they will enhance the supply of organic carbon to favor bio-reduction, particularly if the supply of organic carbon at MMW020 is due to the cause cited in the same paragraph (i.e., "infiltrating seep/spring water contains some dissolved organic content after infiltrating through waste rock and debris in the pit bottom, and this enhances biological activity"). Won't the earthwork (grading) and solids cover be designed to eliminate such infiltration of seep/spring water? Also, the conclusion quoted above is silent about MNA distal from the source – isn't this were the remedy intends for MNA to function?

P4 Response (SC-13)*: It does seem likely that the source of selenium and carbon are both related to the spring and seep water infiltration into the Wells Formation near MMW020, but further investigation of the groundwater chemistry at that location is needed to develop a more complete understanding of the apparent attenuation mechanisms. At this time, it is still an assumption that biological reduction is responsible for the observed attenuation. However, assuming the following:*

- *Biological reduction is occurring at the location,*
- *The source of selenium is the same as the carbon, and*
- *The supply of both selenium and carbon is significantly reduced as the result of the remedy.*

Then it is probable that enough carbon will be present to reduce the selenium concentration to less than the MCL at that location.

That hypothesis is based on the observation that such a reduction already occurs during periods of low recharge. If there is carbon, then the greater the excess, the greater the area of attenuation may be as the carbon disperses into the Wells Formation. Attenuation at the MMW020 location appears to be very effective and relatively rapid, and removal of the source of oxygenated, selenium enriched infiltration, would allow any biochemical attenuation processes to quickly dominate. Attenuation in the more distal portions of the Wells Formation (e.g., MMW006) may be more dependent upon the primarily sorption mechanisms measured in Table 3-2 for the Smoky Canyon project.

14. P. 3-16; The statement MNA will be "immediately effective" once the source is controlled is speculative at this point. Please adjust.

    P4 Response (SC-14)*: Based on the trends and data from MMW020, attenuation is already occurring at that location. Once the ongoing source of COCs is reduced or removed, there is no reason to believe that selenium concentrations will not begin to decrease. Therefore, "immediately effective" is not speculative. However, the term "immediately effective" is not defined, and the sentence will be rewritten as follows (new text in red):*

    > ***"****However, at a minimum, it appears that once the source is controlled, ~~MNA will be~~ attenuation processes will ~~immediately effective~~ begin to reduce selenium concentration in the aquifer initially closest to the source."*

15. P. 3-18, 1st sentence. This sentence is missing a word, such as "for" between "Site" and "the".

    P4 Response (SC-15)*: Agreed. This revision will be made in the revised memorandum.*

16. P. 3-19, 1st bullet. See specific comment 1 above.

    P4 Response (SC-16)*: Agreed. The same revisions as SC-1 to change "substantially remove" to "significantly reduce" will be made in the revised memorandum.*

17. P. 4-1, Pre-Design Studies and Aquifer Material Characterization sections. Suggest that any treatability testing designed to evaluate Se attenuation potential consider both existing conditions and projected future conditions.

    P4 Response (SC-17)*: The details for future studies and testing will be specified in a Pre-Design MNA SAP as discussed in Section 4.0. The text in Section 4.1 will be revised to include a statement that pre-design testing will consider both existing and projected future conditions.*

APPENDIX A-3

A/T Additional Comments on *P4's Ballard Mine Supplemental Technical Memorandum, Monitored Natural Attenuation Remedy for Groundwater, Draft Final Rev 1, October 2017*

Transmitted to P4 on October 26, 2017

From: Tomten, Dave <Tomten.Dave@epa.gov>
Sent: Thursday, October 26, 2017 12:18 PM
To: Barry Myers (bmyers@blm.gov); Bruce Narloch (Bruce.Narloch@stantec.com); Bruce Olenick; Cary Foulk (cfoulk@integrated-geosolutions.com); Colleen O'Hara; COOPER, RANDALL LEE [AG/1000]; Tomten, Dave; Dennis Smith (dennis.smith2@ch2m.com); Emily Yeager (emily.yeager@stantec.com); Gary Billman; Jeff Cundick; Jeff Schut (jeff.schut@ch2m.com); Jeremy Moore (jeremy_n_moore@fws.gov); Wallace, Joe; Kelly Wright; Leah Wolf Martin (leah@wolfmartininc.com); LEATHERMAN, CHRIS R [AG/1850]; Maley, Timothy; Michael Rowe; Norka Paden (Norka.Paden@deq.idaho.gov); PRICKETT, MOLLY [AG/1850]; Randy Vranes; Sandi Fisher; shannon ansley; Shephard, Burt; Stifelman, Marc; Stumbo, Sherri A -FS; (b) (6) ; Vance Drain (vance.drain@stantec.com)
Subject: Additional review comments on MNA Tech Memo

Molly –

Below are additional, minor, review comments on the revised MNA tech memo. If you have any questions or would like to discuss any these comments, please let me know. If you don't have questions or concerns, please incorporate changes, and re-issue for final review and approval. Thanks.
Dave

General Comments

In general, the technical memorandum (TM) is improved over the previous version. However, the document has many minor grammatical/editorial flaws and would benefit from general editing, once the changes are incorporated.

Specific Comments

1. The abbreviation COC is introduced in Sec 2.1.3, and widely used throughout the document. However, the site COCs are never specified. (Similarly, the use of the words constituents and contaminants is ambiguous without specifying what is meant.) Sec. 2.2 mentions some COCs (As, Cd, Se), and provides the helpful statement about Se being the primary COC and the focus of the discussion, but that doesn't appear until some 17 pages into the document. Suggest that the site COCs be presented early on (e.g., where COC is defined), and the point about Se be made there as well. Also, should use caution in using COCs, if you're really talking specifically about Se.

2. Sec. 2.1.4, Page 2-5, last paragraph. Last sentence……*"well-defined" COC plumes emanating* … There are a number of alluvial plumes, some of which are better defined than others, and it's questionable that all are "*well-defined*" based on the limited number of monitoring wells on-site (and the fact that more are proposed as part of the remedial design). Unless you are confident the plumes are "*well-defined*", rephrase the statement to reflect some uncertainty (i.e. something along the lines of … a general understanding of the areas where selenium-impacted groundwater have been detected based on the existing groundwater monitoring network is depicted on Figure X, or/and "reasonably well-defined").

3. Sec. 2.1.5, Wells Formation Aquifer. The statement is made that: "The same observation has been made in the Wells Formation at other mines in the phosphate district including the Dry Valley Mine." Sentences like this should be supported by a literature citation whenever possible.

4. Section 2.1.5 – Plumes ….. Recommend adding a data table summarizing groundwater data, including the concentration range of the three COC(s) detected in each aquifer. This will complement the figures in the document. I believe the concentrations are overall quite low and/or near background concentrations which would further support the MNA component of the remedy.

5. Sec. 2.2, paragraph 2. MCL = Maximum Contaminant <u>Level</u>, not Limit.

6. Sec. 2.3, paragraph 1. The sentence: "MNA will be used as a polishing step to address contamination that has already been released to shallow groundwater" is good, but suggest extending it to say something like ", while source controls and PRBs will be used to mitigate future releases and ICs will be used to prevent groundwater use while MNA is underway, until groundwater cleanup levels are achieved".

7. Sec. 2.4, paragraphs 5 and 6. To improve flow, suggest switching the order of the paragraphs about ICs and LTM. Then, at the end of the LTM paragraph something like, "Use of MNA as a remedy component requires collection and analysis of data, as part of the LTM program, to evaluate and demonstrate MNA performance." (It is hoped that this will provide a segue to the next paragraph on tiered approach for evaluating MNA.)

8. Sec. 3.1.2, paragraph 2. The first sentence is confusing, apparently due to the two possible meanings of the word "reduction". Think you mean to say that biologically-mediated (microbial) reduction [e.g., of selenite] is the primary process responsible for Se <u>removal</u> or <u>attenuation</u> [i.e., reduction in groundwater Se concentration]. Saying Se reduction could be interpreted to mean chemical reduction in Se redox state, which would make the sentence nonsensical.

9. Section 3.2.1 – 2nd paragraph. Not sure what is meant by "*slowly advancing plumes (when compared to convective groundwater velocity)*". This seems like a general statement. Either support with definitive sampling data showing the plumes advancing, or leave this statement out.

10. Section 3.2.2 …. Now included: "*Phase I Evaluation of Contaminant Trends*". This implies there are subsequent phases. Include a lead-in discussion of the Evaluations performed in this regard (assuming there is a Phase II, III, etc.…, which could be carried over into the performance monitoring stage (included/part of Pre-design studied)).

11. Sec. 3.2.2, paragraph after Figure 3-3. Saying that MMW006 and MMW021 show a lagged/muted response to concentrations in MMW020 seems like a stretch based solely on the data plotted in Figure 3-3. Recommend re-ordering the list of bullets, as it may be more credible to make that statement after you've presented the hypothetical explanation as found in the subsequent bullets.

12. Table 3-1. Should give the source for all values shown in the table (the text above says <u>some</u> of the data are from the Smoky Canyon document, indicating that some are from other sources). If the values shown for the literature line item are from another report rather than from literature independently reviewed by the Ballard team, should just cite the source report.

13. Sec. 3-3, 3rd from last bullet. Location should be plural – need more than one new MW.

____

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Ballard Mine Remedial Investigation and Feasibility Study
SUPPLEMENTAL TECHNICAL MEMORANDUM MONITORED NATURAL ATTENUATION REMEDY FOR GROUNDWATER
(OCTOBER 2017)

COMMENTING A/T: IDEQ

Item No.	Section; Table; Figure	Page	Paragraph	Line (if not obvious)	Agency/Tribes Comment	Did P4 Respond to Comment?
					General Comments	
	Be consistent on whether the word "data" is singular or plural. Plural is preferred.					
					Specific Comments	
	1.1	1-1	2	2	Change "corner-stone" to "cornerstone."	
	1.2	1-1	3 (last)	4	Change "comment" to "comments" to read "… P4 responses to A/T comments …"	
	2.1	2-1	2	1	Change to "… Soda Springs, Caribou County, Idaho …"	
	2.1.1	2-1	3	2	Change to "… Basin and Range and Rocky Mountain Physiographic Provinces."	
	2.1.1	2-1	4 (last)	4	Change "SE" to "southeast."	
	2.1.1	2-2	1 (partial)	5 (last)	Change "depict" to "depicts" to read "… **Drawing 2-4** depicts cross-sections …" for subject-verb agreement.	
	2.1.3	2-3	4 (last)	6	Change "proposed" to "preliminary" to read "… preliminary cleanup levels (PCLs)."	
	2.1.4	2-7	2	5	Change "makes" to "make" to read "… the Wells Formation and make direct …" for subject-verb agreement.	
	2.1.4	2-7	4 (last)	5	Change "are" to "is" to read "… bedding at the sites is disrupted …" for subject-verb agreement.	
	2.1.5	2-8	1	9	Insert "a" to read "… center plume has a length …"	
	2.1.5	2-8	2	9	Delete ", to the Blackfoot River alluvium."	
	2.1.5	2-8	2	10 (last)	Change "west-side" to "west side" for consistency.	
	2.1.5	2-9	5 (last)	3	Insert "the" to read "… southwestern side of the Site …"	
	2.1.5	2-9	5 (last)	8	Change "with" to "within" to read "… impacted groundwater within the Wells Formation …"	
	2.2	2-11	1 (partial)	4	Delete "at" and insert "as part of" to read "… monitoring wells sampled as part of the Ballard, Henry, and Enoch Valley RIs …"	
	2.2	2-11	1 (partial)	7	Change "are" to "is" to read "…environmental receptors could be affected is the Henry Springs…" for subject-verb agreement.	
	2.2	2-11	1 (partial)	10	Change "are" to "is" to read "…at the Ballard Site is unlikely …" for subject-verb agreement.	
	2.3	2-11	3	8	Delete "following the RA" to read "… near the sources areas and along the Blackfoot River corridor."	
	2.3.2	2-13	3	5	Change "designing" to "design" to read "… (Golder's) cover design modeling effort …"	
	2.3.2	2-13	2	4	Delete "that" to read "… textured alluvial material is available near the Site …"	
	2.3.2	2-13	3	2	Delete "of" and insert a hyphen to read "… (an approximately 13-fold reduction …"	
	2.3.2	2-13	4	7	Change "eastside" to "east side" for consistency.	
	2.4	2-19	2 (last)	4	Delete "be" to read "… groundwater restoration is more likely to occur …"	
	3.1.2	3-2	2	3	Change "selenate [Se^{+6}]" to "selenate [Se^{+}6]" for consistency.	
	3.1.2	3-2	3	3	Delete the comma to read "Hay et al. (2016)" here and all other occurrences to be consistent with the other citations.	
	3.1.2	3-2	4	2	Delete the semicolon and comma to read "… attenuation process although some less important …"	
	3.2.1	3-5	1	5	Delete the comma to read "… change, whereas if it is due …"	
	3.2.1	3-5	1	7	Insert "on" to read "… focused on the concept …"	
	3.2.1	3-5	3 (last)	4	Change "presented" to "present" to read "… not present on the Ballard Site."	
	3.2.1	3-8	1 (partial)	1	Change "suboxic" to "sub-oxic" for consistency.	

Ballard Mine Remedial Investigation and Feasibility Study SUPPLEMENTAL TECHNICAL MEMORANDUM MONITORED NATURAL ATTENUATION REMEDY FOR GROUNDWATER (OCTOBER 2017)						
COMMENTING A/T: IDEQ						
Item No.	Section; Table; Figure	Page	Paragraph	Line (if not obvious)	Agency/Tribes Comment	Did P4 Respond to Comment?
	3.2.1	3-8	2	4	Insert a hyphen to read "… the mine-affected alluvial …"	
	3.2.1	3-8	3	Sentence 3	Change to "Additional alluvial groundwater sampling during pre-design studies along plume boundaries (as discussed in Section 4.0) and evaluation of Se:SO_4 ratios and DO and ORP measurements, as well as general water quality parameters (total organic carbon, ferrous/ferric iron, selenium species, and other trace metals/non-metals), will be useful in determining if selenium attenuation processes are active in the alluvial aquifer."	
	Figure 3-3	3-9			Doesn't the secondary y-axis represent total precipitation from October to April? If so change the label to represent that.	
	3.2.2	3-10	1	2	Change "drops" to "drop" to read "… the selenium concentrations in MMW020 drop to near …" for subject-verb agreement.	
	3.2.2	3-10	Bullet 1	2	Insert "to" to read "… flow has to be transported …"	
	3.2.2	3-10	Bullet 2	4	Change the semicolon to a comma to read "… observed in MMW020, however, in a more muted fashion …"	
	3.2.2	3-10	Bullet 4		Change to "Based on the data, the source of contamination detected at MMW006 is the seeps and springs that discharge from the waste rock above the eastern pit highwall. The proposed preferred alternative would significantly reduce and control the sources of contamination to the Wells Formation, including undetected infiltration through the waste rock, by rerouting the spring water and favorably regrading/contouring and covering the adjacent waste rock."	
	3.2.2	3-11	1	3	Delete the first "mine" to read "… several new phosphate mine permitting …"	
	3.2.2	3-11	2	2	Change "attenuations" to "attenuation" to read "Most of the attenuation studies …"	
	3.2.2	3-12	1 (partial)	1	Delete the first "this" to read "… through rerouting of this source …"	
	3.2.2	3-15	2	Sentence 3	Add a hyphen and delete a comma to read "… removal of the source of oxygenated, selenium-enriched infiltration would allow any …"	
	3.2.2	3-15	3	9 (last)	Change "suboxic" to "sub-oxic" for consistency.	
	3.3	3-16	Bullet 2	5	Delete the second "there" to read "… there would be no anticipated …"	
	3.3	3-17	Bullet 4	1	Change to "New monitoring wells located within plume cores …"	
	3.3	3-17	Bullet 5		Change "related" to "relate" to read "Specific aquifer solid material properties that relate to MNA processes."	
	4.1	4-1	2	5	Change to "Preparation of a Pre-Design MNA sampling and analysis plan (SAP) will …"	
	4.1	4-1	4 (last)	3 (last)	Insert "be" to read "…additional confirmation can be made regarding …"	
	4.1.2	4-2	5 (last)	6	Add "turbidity" to read "… (pH, conductivity, DO, ferrous iron, ORP, turbidity, and temperature) …"	
	5				Be consistent on using a period or comma after the author name(s) and before the date. Be consistent on initials occurring before or after the surname for junior authors. Be consistent on whether commas are used after surnames.	
	5	5-1	Martin et al. 2011 citation		Insert "and" to read "… J., and Wallschläger …"	
	5	5-2	USEPA 2009 citation		Delete "(U.S. Environmental Protection Agency)" to read "USEPA, 2009."	
	Appenidix A				Delete one of the two "APPENDIX A COMMENTS AND COMMENT RESPONSE DOCUMENTS" pages.	

APPENDIX A-4

P4 Additional Responses to A/T Comments (dated October 26, 2017) on *P4's Ballard Mine Supplemental Technical Memorandum, Monitored Natural Attenuation Remedy for Groundwater, Draft Final Rev 1, October 2017*

Submitted to A/Ts on November 13, 2017

A/T Comments and P4's Responses on Ballard Mine Feasibility Study (FS) Supplemental Technical Memorandum Monitored Natural Attenuation Remedy for Groundwater (Draft Final Revision 1, October 2017)

General Comments

1. In general, the technical memorandum (TM) is improved over the previous version. However, the document has many minor grammatical/editorial flaws and would benefit from general editing, once the changes are incorporated.

   ***P4 Response (GC-1)**: The final version of the memorandum has been reviewed by a technical editor and revised for grammatical/editorial corrections.*

Specific Comments

1. The abbreviation COC is introduced in Sec 2.1.3, and widely used throughout the document. However, the site COCs are never specified. (Similarly, the use of the words constituents and contaminants is ambiguous without specifying what is meant.) Sec. 2.2 mentions some COCs (As, Cd, Se), and provides the helpful statement about Se being the primary COC and the focus of the discussion, but that doesn't appear until some 17 pages into the document. Suggest that the site COCs be presented early on (e.g., where COC is defined), and the point about Se be made there as well. Also, should use caution in using COCs, if you're really talking specifically about Se.

   ***P4 Response (SC-1)**: A discussion of Ballard Mine Contaminants of Concern (COCs) consistent with the Ballard Mine RI and FS reports has been included in Section 2.1.3. The document has been revised to consistently refer to COCs or a specific COC. Use of other terms such as constituent, contaminant, or chemical has been defined or revised, as applicable.*

2. Sec. 2.1.4, Page 2-5, last paragraph. Last sentence……*"well-defined" COC plumes emanating* … There are a number of alluvial plumes, some of which are better defined than others, and it's questionable that all are "*well-defined*" based on the limited number of monitoring wells on-site (and the fact that more are proposed as part of the remedial design). Unless you are confident the plumes are "*well-defined*", rephrase the statement to reflect some uncertainty (i.e. something along the lines of … a general understanding of the areas where selenium-impacted groundwater have been detected based on the existing groundwater monitoring network is depicted on Figure X, or/and "reasonably well-defined").

   ***P4 Response (SC-2)**: This sentence has been revised to state "reasonably well-defined"*

3. Sec. 2.1.5, Wells Formation Aquifer. The statement is made that: "The same observation has been made in the Wells Formation at other mines in the phosphate district including the Dry Valley Mine." Sentences like this should be supported by a literature citation whenever possible.

   ***P4 Response (SC-3)**: The cited sentence was a personal communication with P4 professional personnel. Given the nature of the statement, we have elected to delete it opposed to referencing it.*

4. Section 2.1.5 – Plumes ….. Recommend adding a data table summarizing groundwater data, including the concentration range of the three COC(s) detected in each aquifer. This will complement the figures in the document. I believe the concentrations are overall quite low and/or near background concentrations which would further support the MNA component of the remedy.

__P4 Response (SC-4)__: As noted in the comment, summary statistics for selenium in Site monitoring wells are provided on Drawing 2-8 and selenium concentrations are also included for the direct-push borings and monitoring wells on the plume maps provided on Drawings 2-6 and 2-7. For completeness, a summary table of concentration data for the COCs arsenic, cadmium, and selenium has been included in the revised memorandum as referenced in Section 2.1.3.

5. Sec. 2.2, paragraph 2. MCL = Maximum Contaminant Level, not Limit.

   __P4 Response (SC-5)__: This revision has been made in the revised memorandum; however, the reference to MCLs now occurs in Section 2.1.3 in response to SC-1.

6. Sec. 2.3, paragraph 1. The sentence: "MNA will be used as a polishing step to address contamination that has already been released to shallow groundwater" is good, but suggest extending it to say something like ", while source controls and PRBs will be used to mitigate future releases and ICs will be used to prevent groundwater use while MNA is underway, until groundwater cleanup levels are achieved".

   __P4 Response (SC-6)__: Agreed. The sentence has been revised to include the edits suggested by the commenter.

7. Sec. 2.4, paragraphs 5 and 6. To improve flow, suggest switching the order of the paragraphs about ICs and LTM. Then, at the end of the LTM paragraph something like, "Use of MNA as a remedy component requires collection and analysis of data, as part of the LTM program, to evaluate and demonstrate MNA performance." (It is hoped that this will provide a segue to the next paragraph on tiered approach for evaluating MNA.)

   __P4 Response (SC-7)__: Agreed. The memorandum has been revised to switch the paragraphs and include the proposed sentence as a transition to the discussion of the EPA's tiered-approach for MNA.

8. Sec. 3.1.2, paragraph 2. The first sentence is confusing, apparently due to the two possible meanings of the word "reduction". Think you mean to say that biologically-mediated (microbial) reduction [e.g., of selenite] is the primary process responsible for Se removal or attenuation [i.e., reduction in groundwater Se concentration]. Saying Se reduction could be interpreted to mean chemical reduction in Se redox state, which would make the sentence nonsensical.

   __P4 Response (SC-8)__: Agreed. The sentence has been revised to include the edits suggested by the commenter.

9. Section 3.2.1 – 2nd paragraph. Not sure what is meant by "*slowly advancing plumes (when compared to convective groundwater velocity)*". This seems like a general statement. Either support with definitive sampling data showing the plumes advancing, or leave this statement out.

   __P4 Response (SC-9)__: The sentence is a general statement introducing the conclusions for the section. The full sentence reads, "The selenium concentration data indicate relatively static plumes or slowly advancing plumes (when compared to the convective groundwater velocity)." It is the concentration data that supports the statement. The parenthetical portion was added to help define what is meant by slowly advancing. It may be that the parenthetical statement implied some other type of analysis was done. It has been deleted.

10. Section 3.2.2 …. Now included: "*Phase I Evaluation of Contaminant Trends*". This implies there are subsequent phases. Include a lead-in discussion of the Evaluations performed in this regard (assuming there is a Phase II, III, etc.…, which could be carried over into the performance monitoring stage (included/part of Pre-design studied)).

__P4 Response (SC-10)__: An introductory discussion of the Phase I evaluations and relationship to future phases discussed in Section 4.0 for both the alluvial and Wells Formation aquifers has been included in Sections 3.2.1 and 3.2.2.

11. Sec. 3.2.2, paragraph after Figure 3-3. Saying that MMW006 and MMW021 show a lagged/muted response to concentrations in MMW020 seems like a stretch based solely on the data plotted in Figure 3-3. Recommend re-ordering the list of bullets, as it may be more credible to make that statement after you've presented the hypothetical explanation as found in the subsequent bullets.

    __P4 Response (SC-11)__: As suggested by reviewer, the bullets have been reordered and edited for clarity in the revised memorandum.

12. Table 3-1. Should give the source for all values shown in the table (the text above says <u>some</u> of the data are from the Smoky Canyon document, indicating that some are from other sources). If the values shown for the literature line item are from another report rather than from literature independently reviewed by the Ballard team, should just cite the source report.

    __P4 Response (SC-12)__: All the data cited were from the Smoky Canyon Mine, Panel F & G Final Environmental Impact Statement FEIS (BLM/USFS, 2007). A citation has been added to the table. The associated text also has been edited to indicate the data were exclusively from the FEIS. The confusion may have arisen because the FEIS reports data from the Smoky Canyon Mine as well as the Dry Valley Mine.

13. Sec. 3-3, 3rd from last bullet. Location should be plural – need more than one new MW.

    __P4 Response (SC-13)__: This revision has been made in the revised memorandum.